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The ENGINEERING DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIX No. 11 NOVEMBER, 1958

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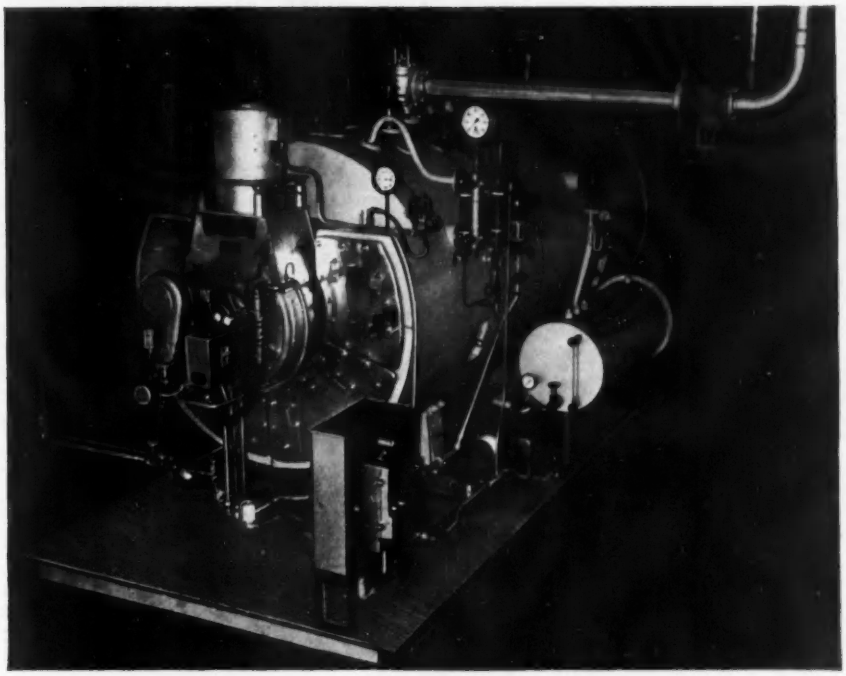

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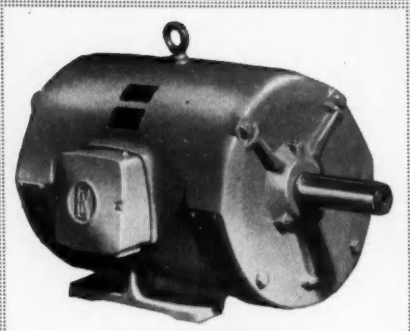

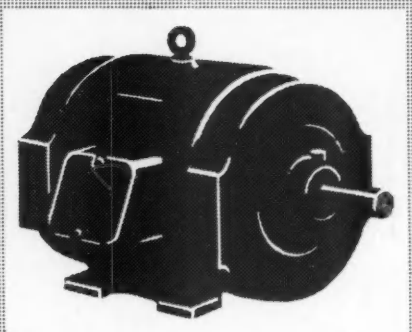

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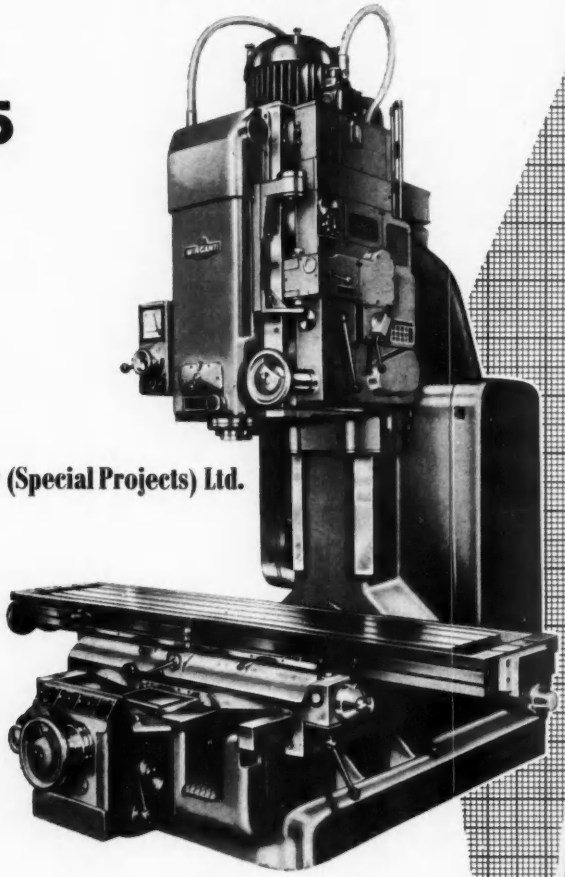

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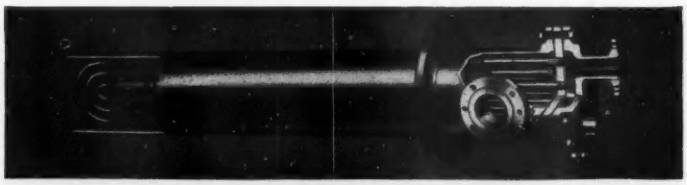

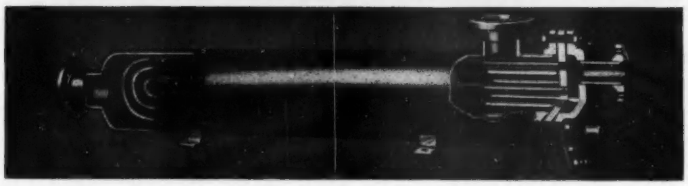

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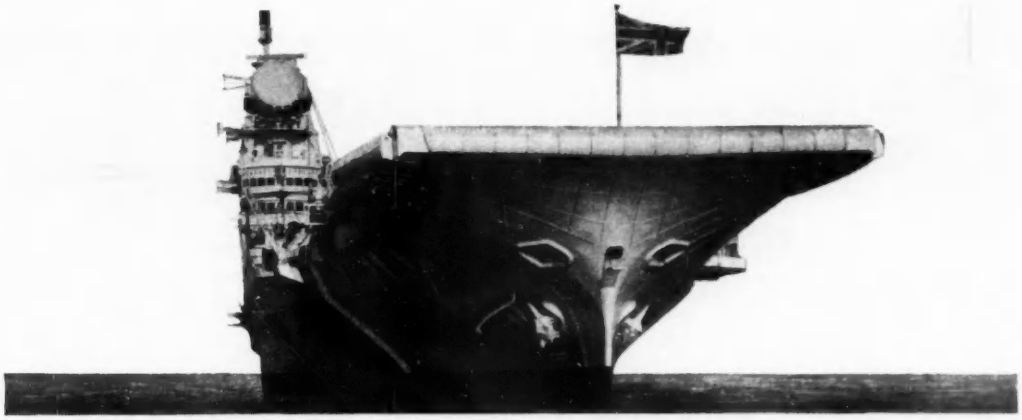

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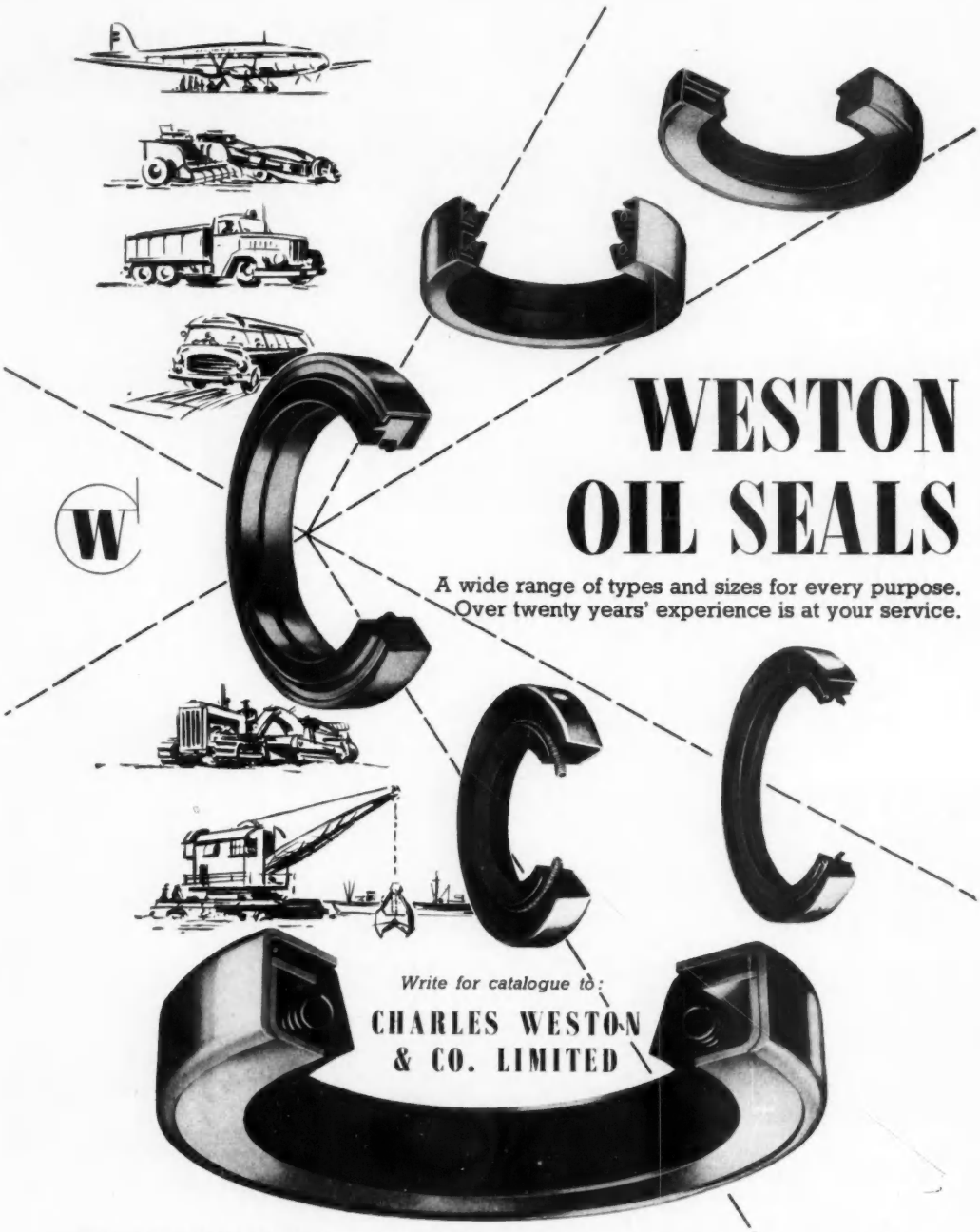

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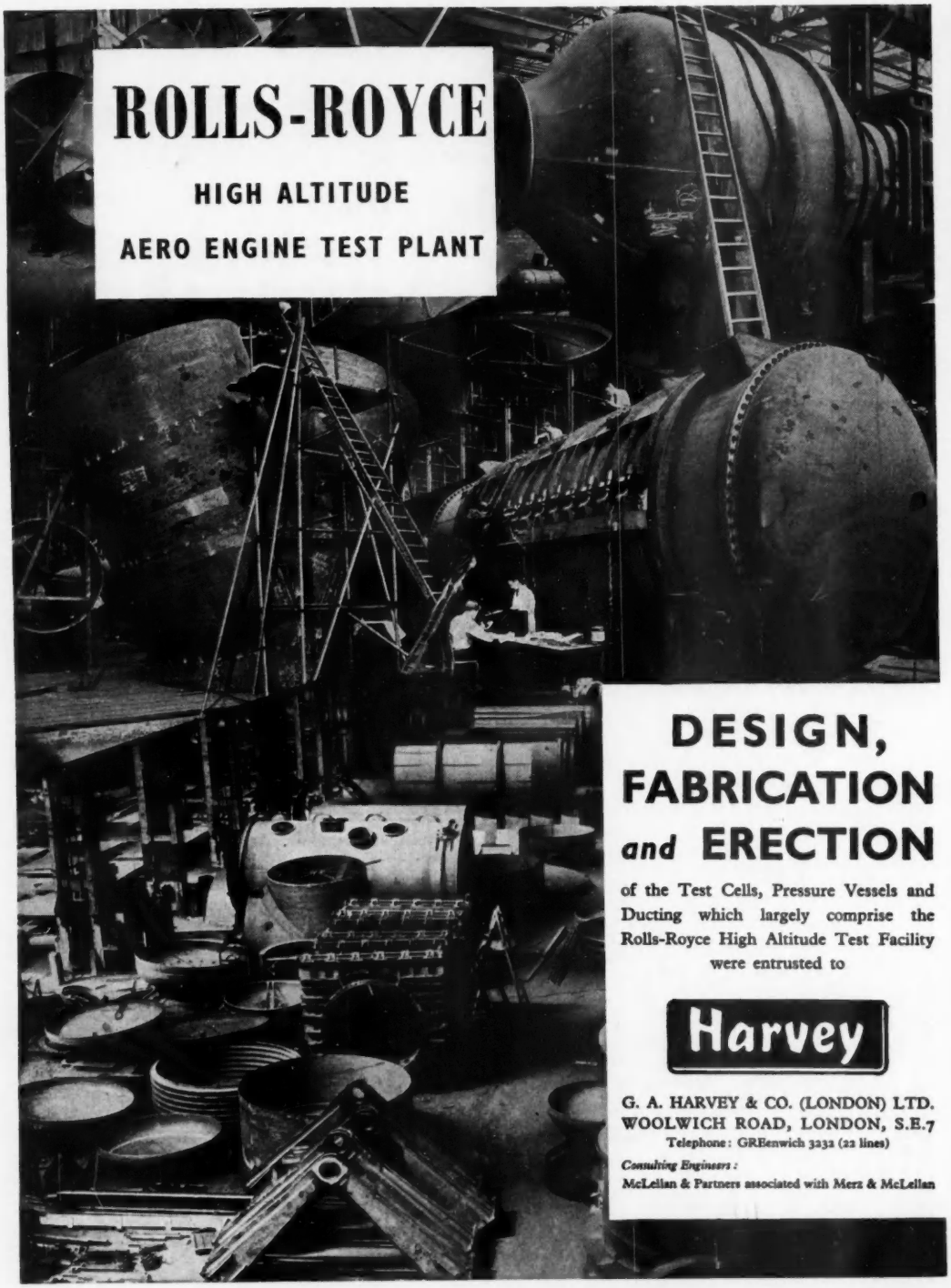

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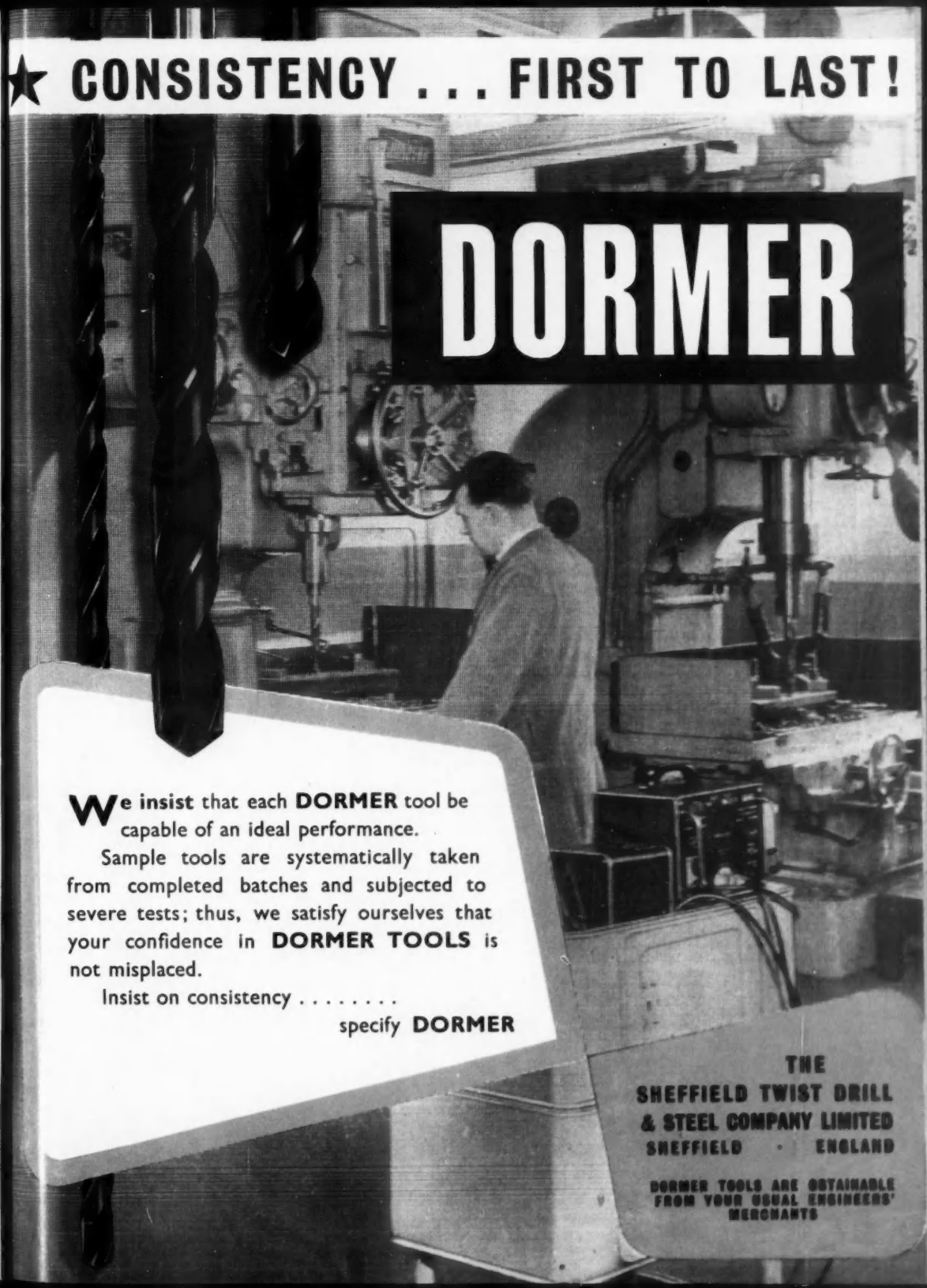
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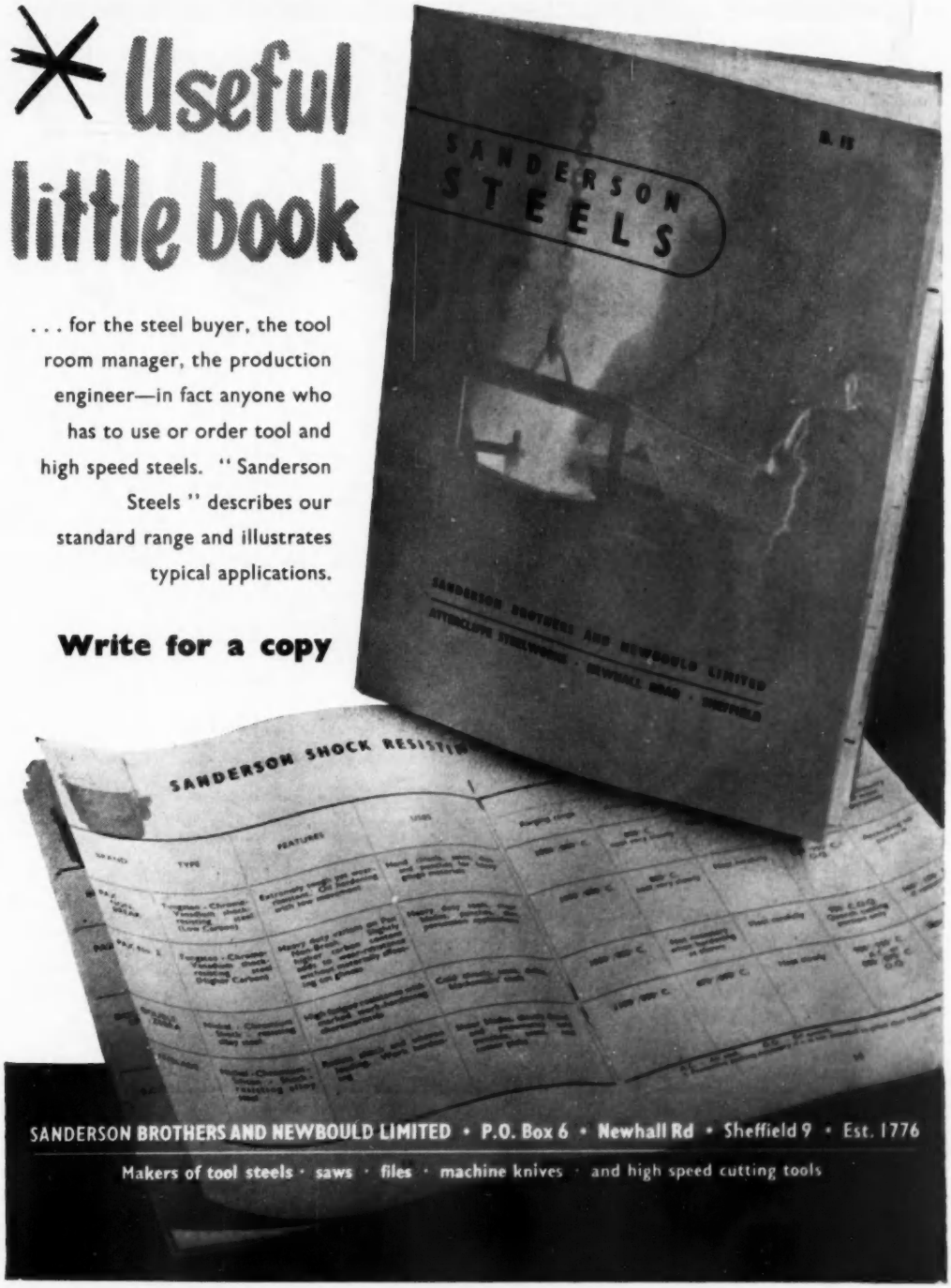

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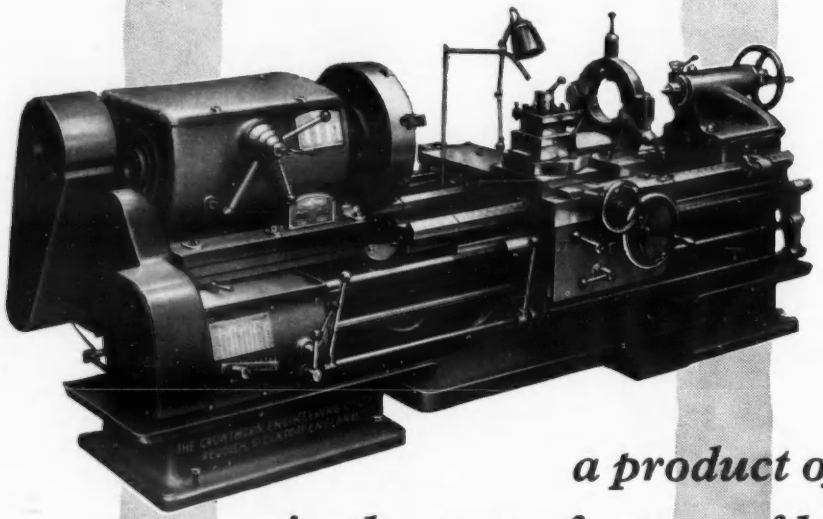

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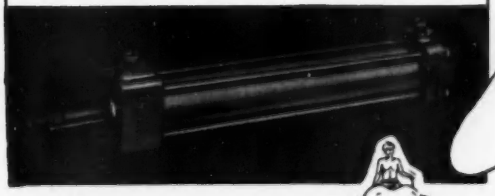

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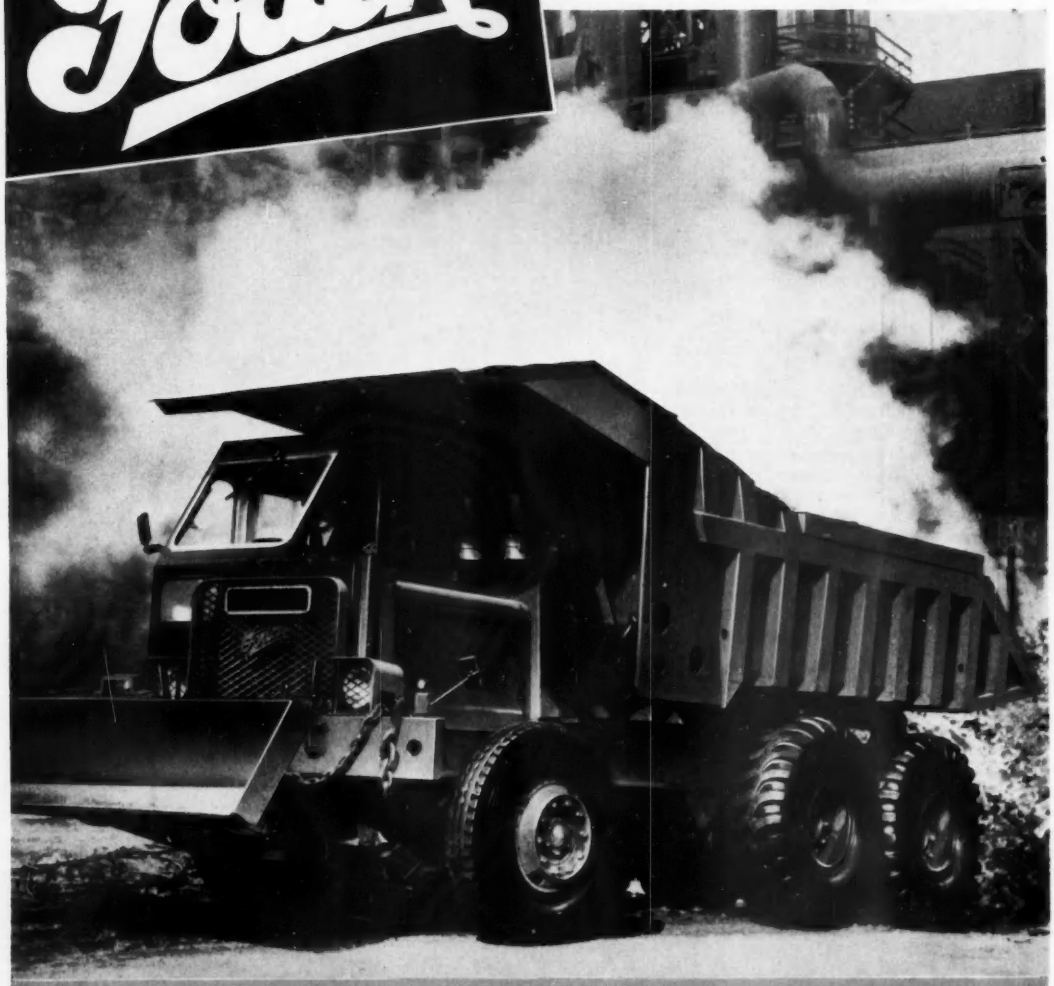

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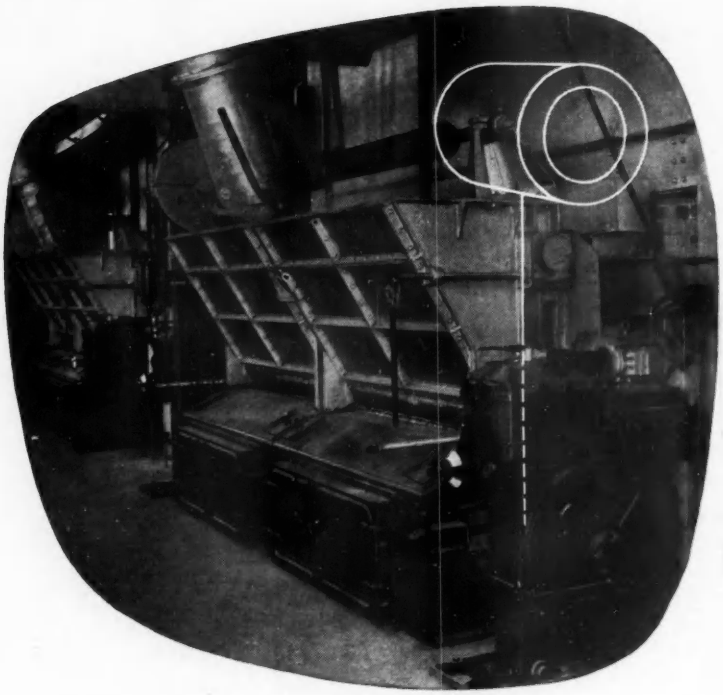

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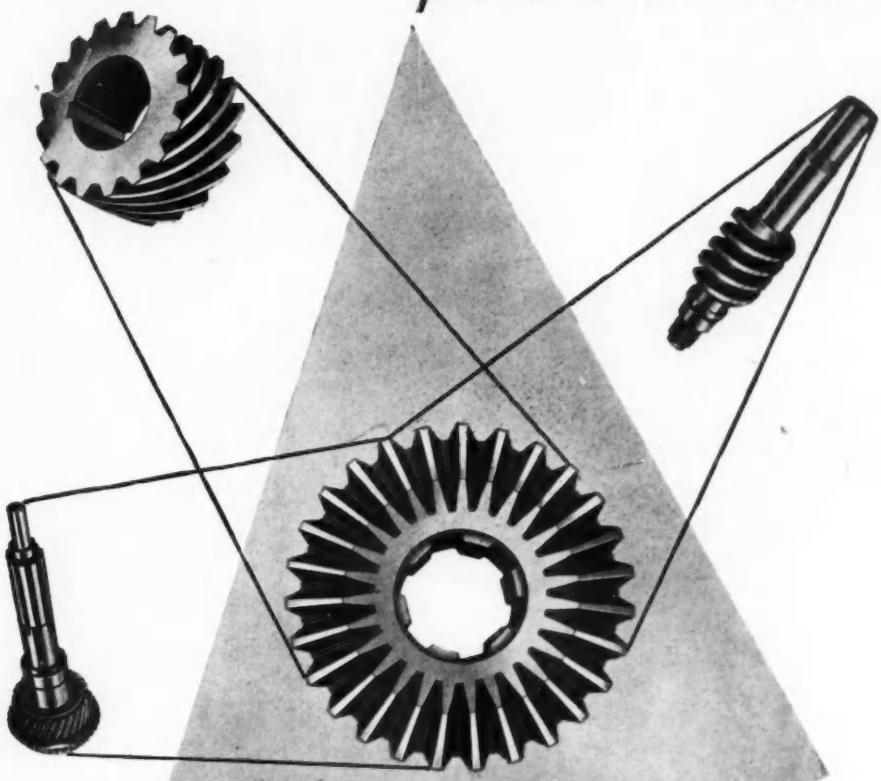

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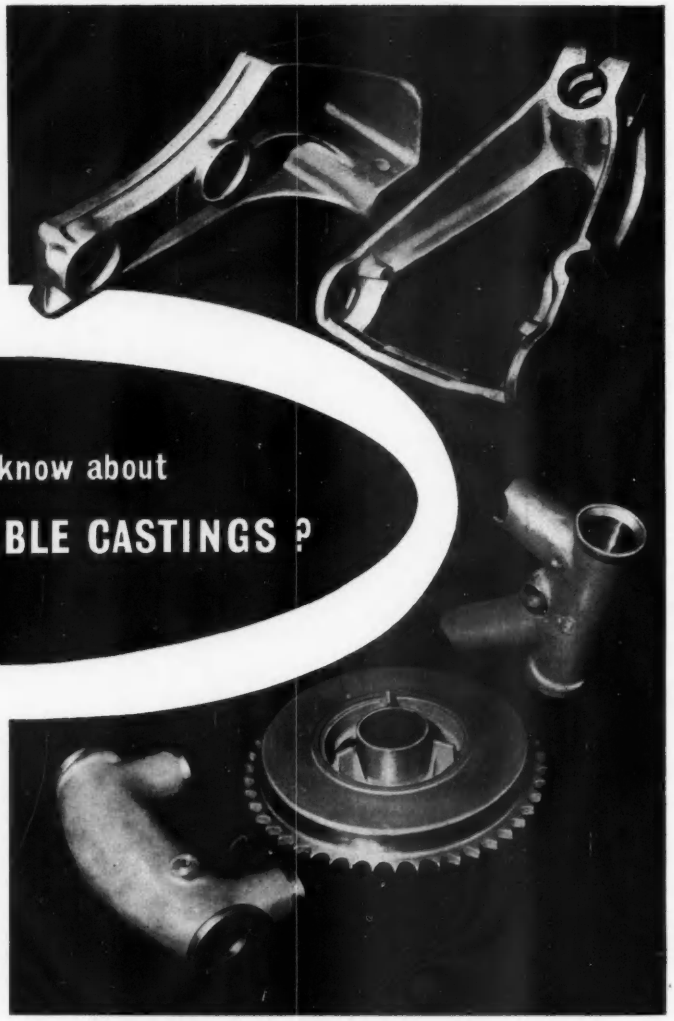

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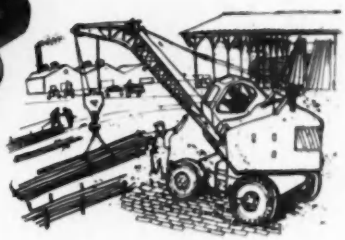

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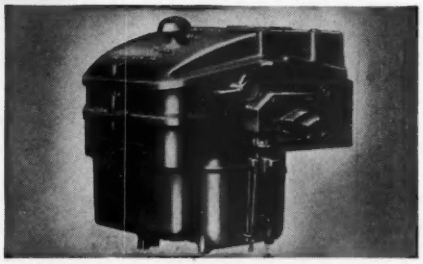

For the new

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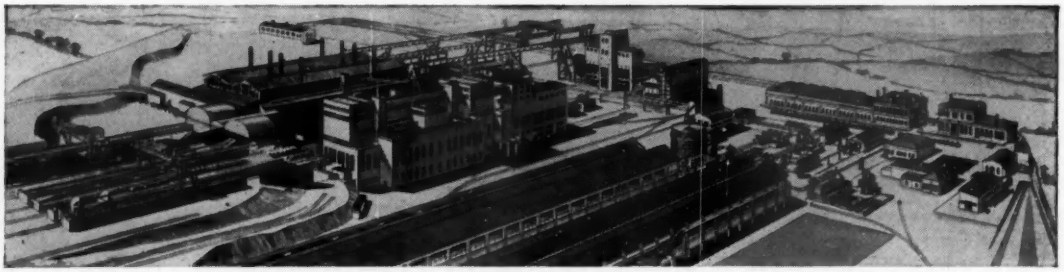

Perspective Drawing by courtesy of the Main Contractors, Woodall Duckham Construction Co. Ltd.

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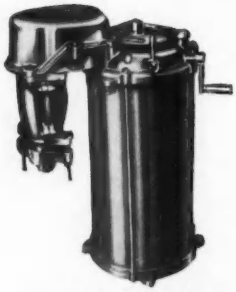
In the reconstructed Provan Works at Glasgow, the Scottish Gas Board has made extensive use of Ellison Switchgear. Some of the equipment is illustrated here. It includes four distribution switchboards as well as many circuit breakers and motor starters.



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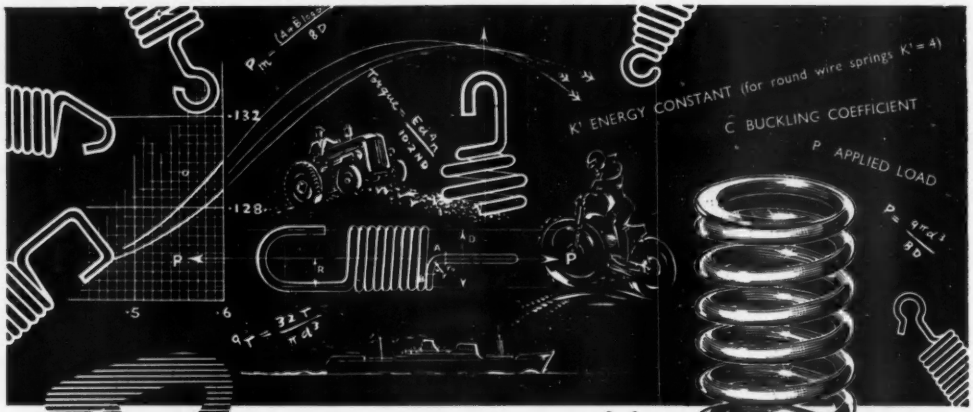

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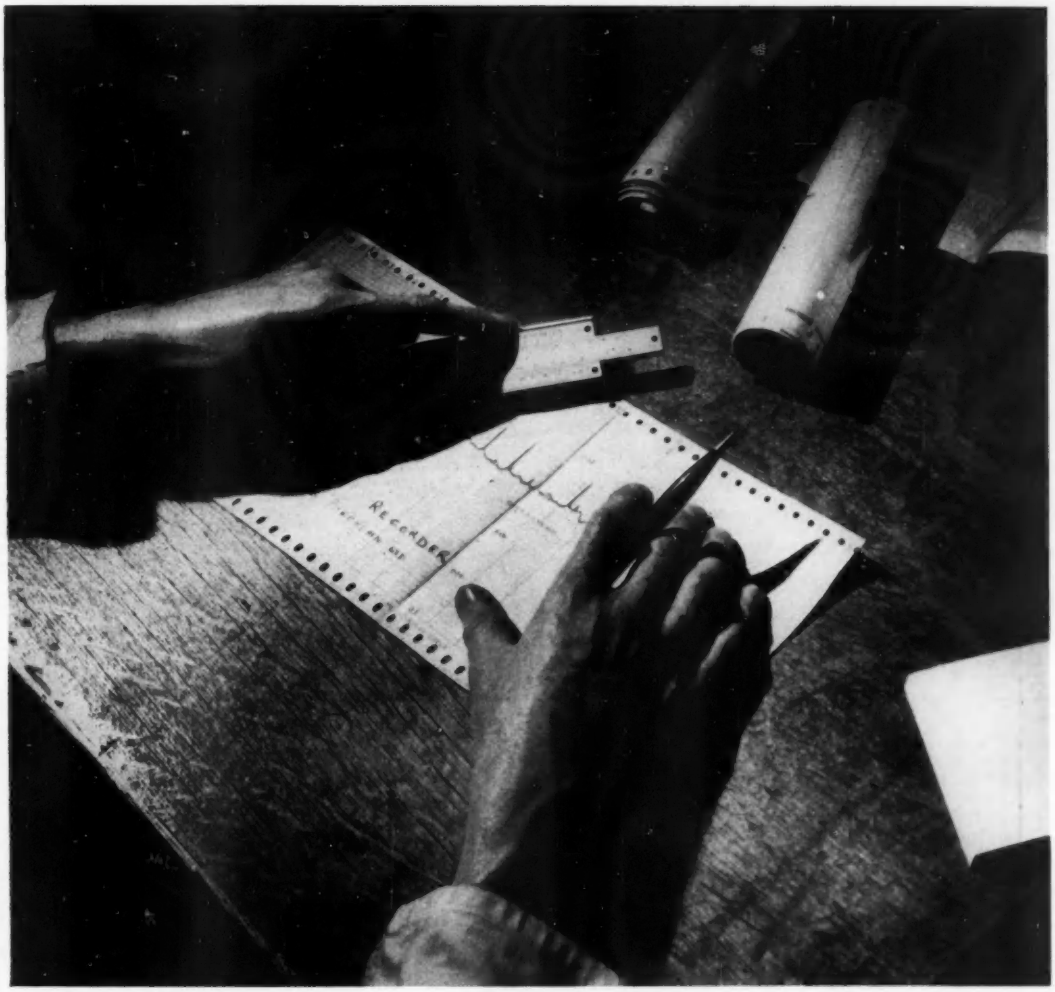

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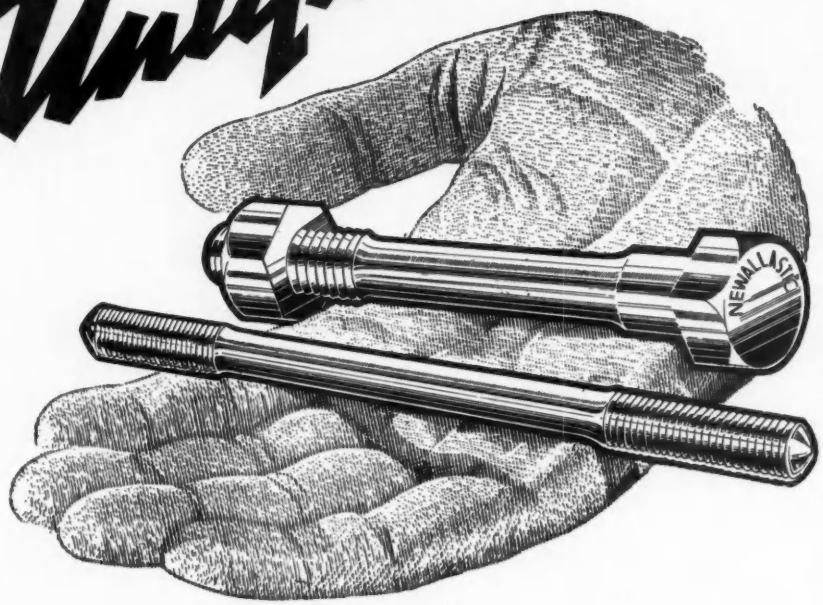

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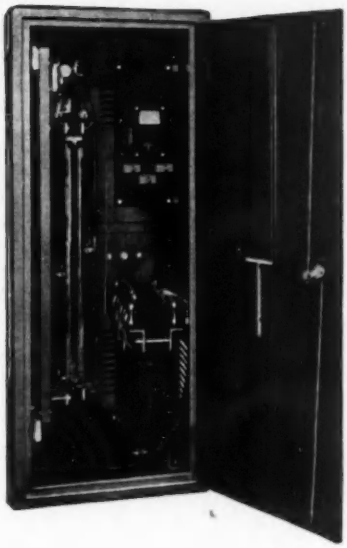

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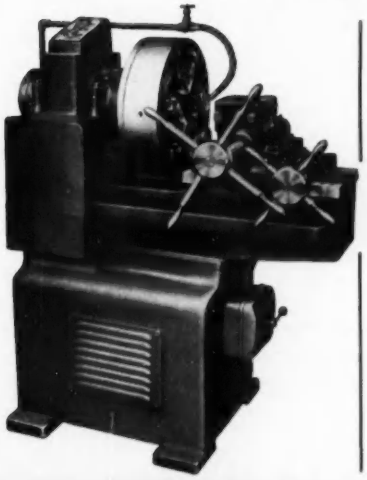

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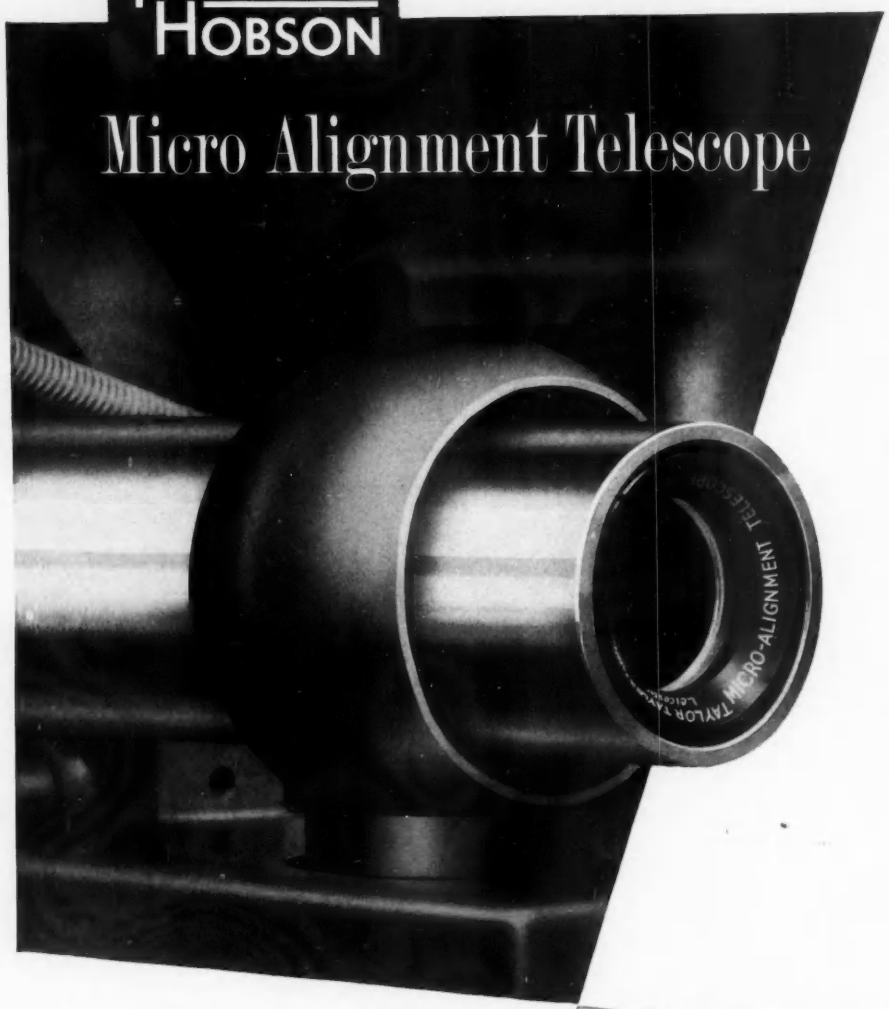

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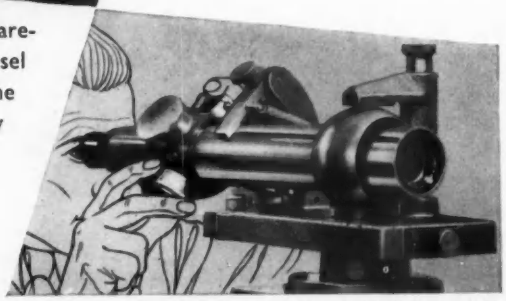

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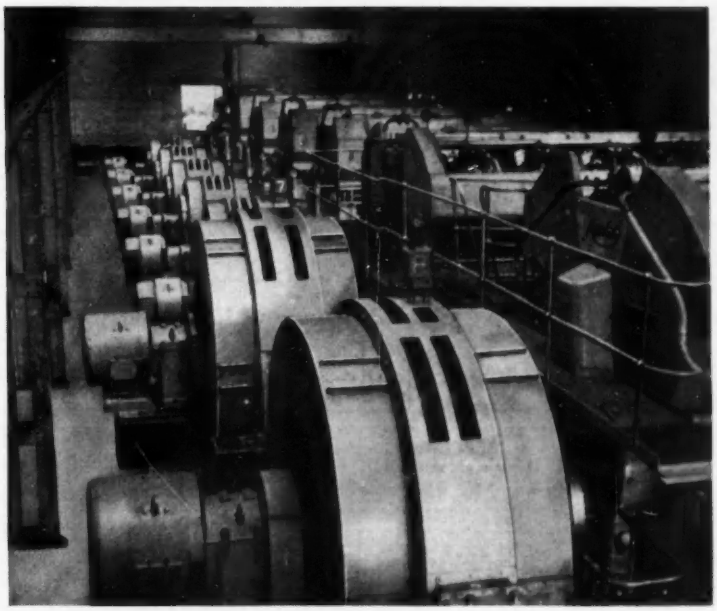

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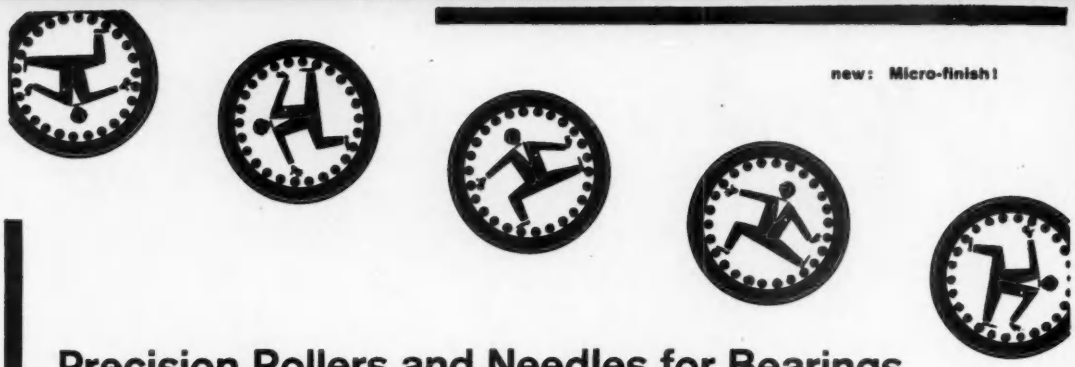

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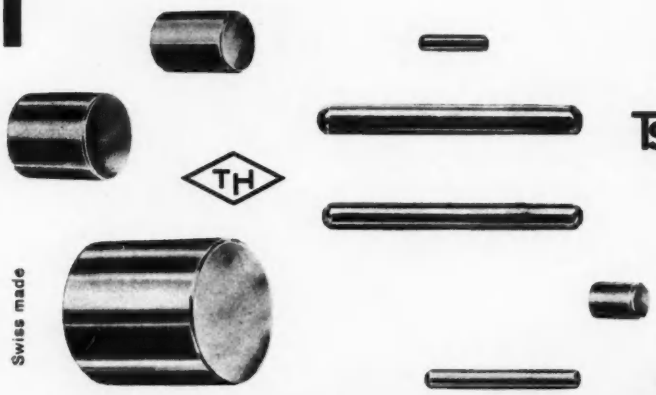

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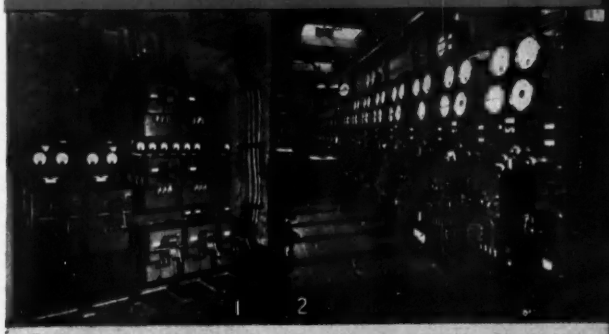

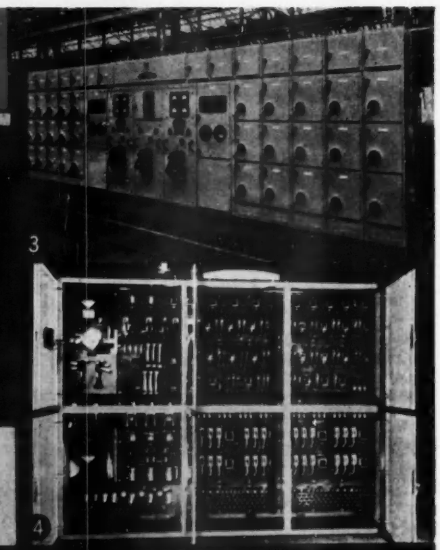

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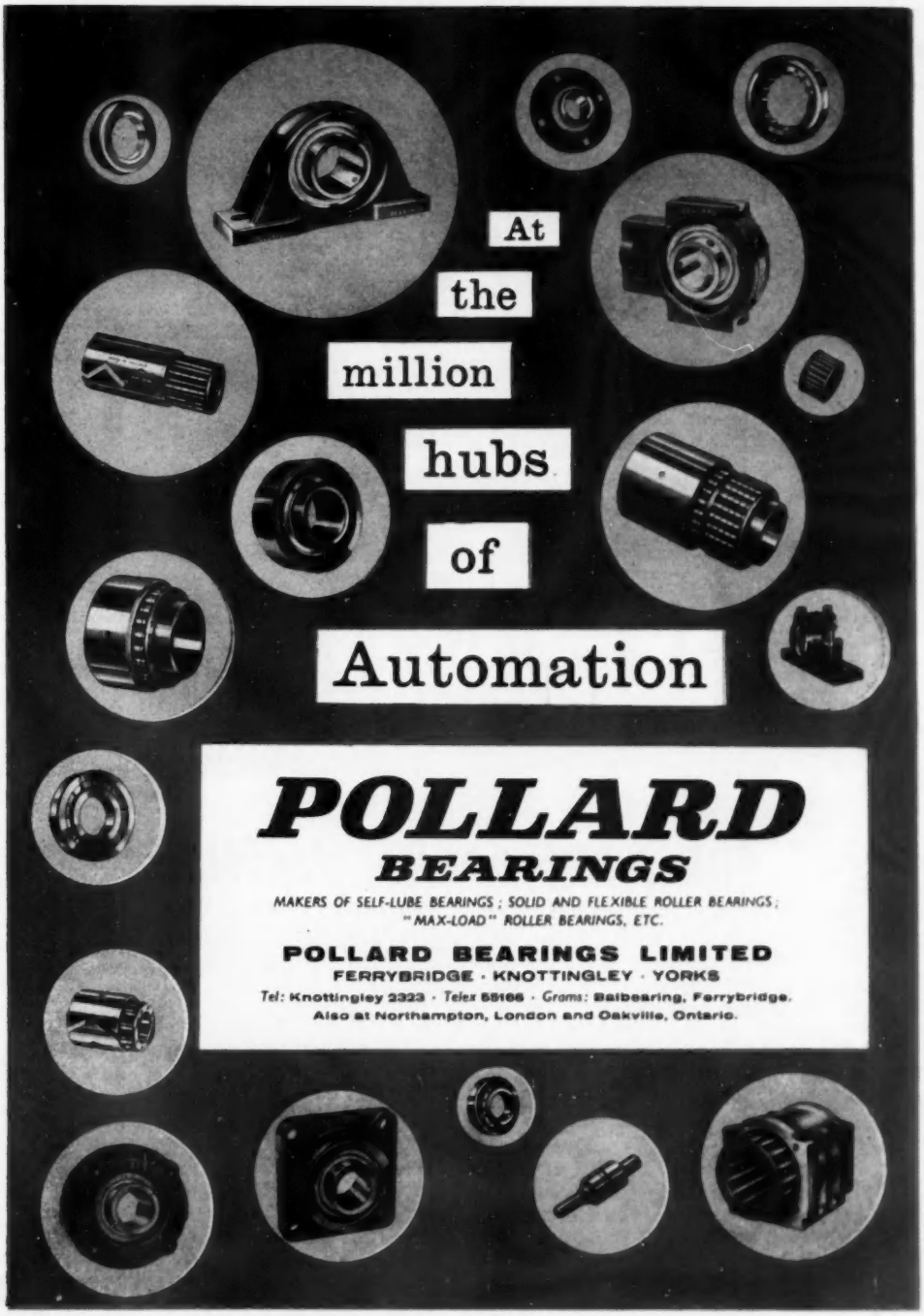
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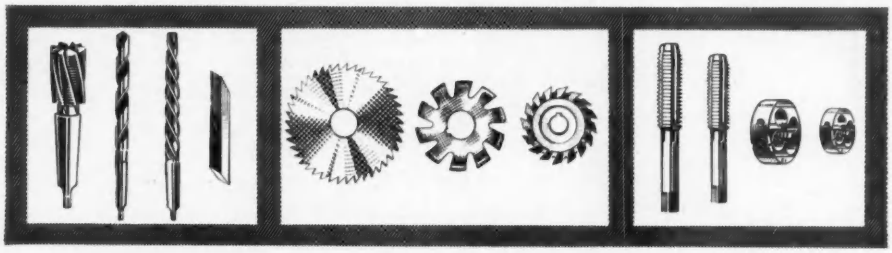

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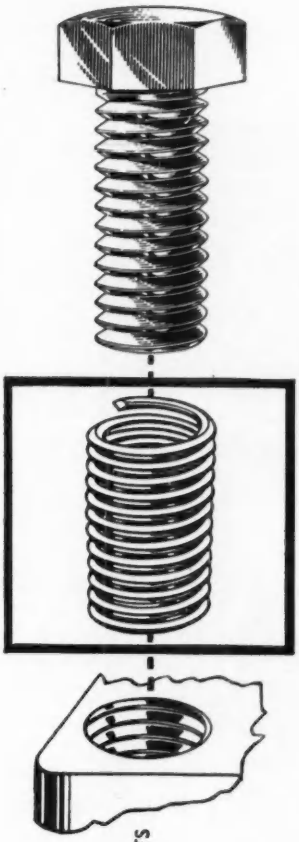

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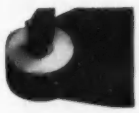
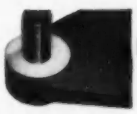
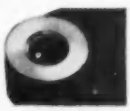
DRILL  **TAP**  **INSTALL** 

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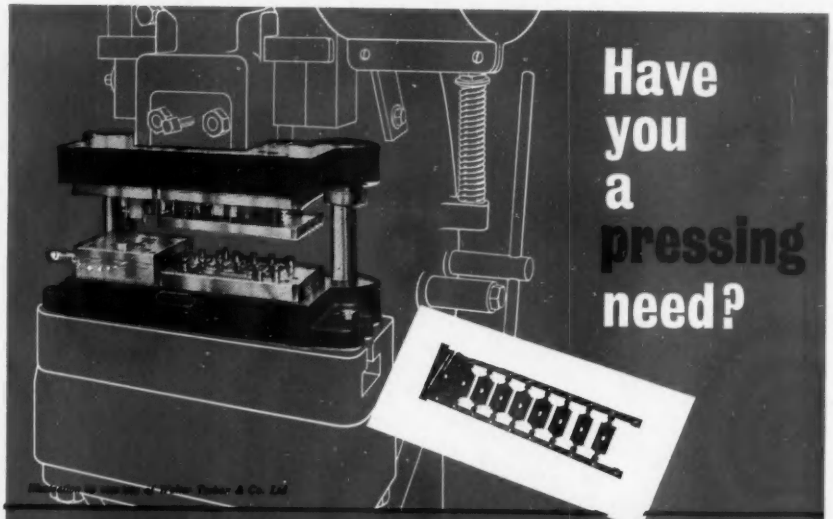

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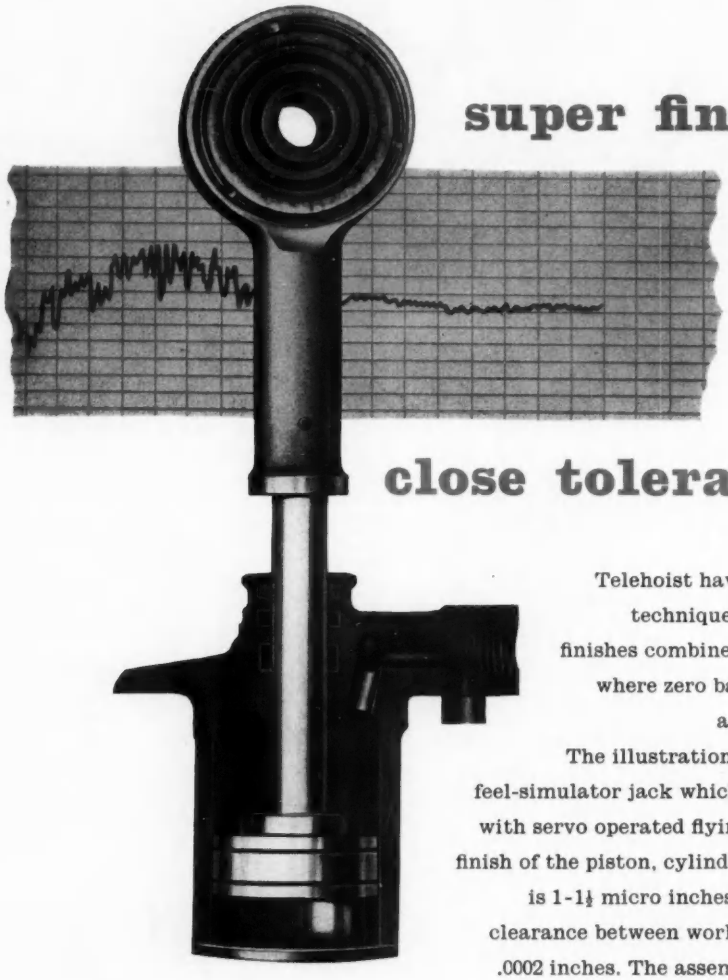

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close tolerances

Telehoist have developed production techniques to attain high surface finishes combined with close tolerances, where zero backlash and low friction are design fundamentals.

The illustration shows an H. M. Hobson feel-simulator jack which is used in conjunction with servo operated flying controls. The surface finish of the piston, cylinder and spherical bearing is 1-1½ micro inches. The concentricity and clearance between working surfaces are within .0002 inches. The assembled units are tested at temperatures of −40°C. and +70°C.

If you have a production application demanding zero backlash and low friction characteristics we should be pleased to investigate and advise.

The illustration is shown by the courtesy of H. M. Hobson Limited.

Telehoist are skilled in

precision production engineering and super finishing

Telehoist Ltd, Manor Road, Cheltenham, *are an associate company of Wilmot Breeden Ltd.*

...that's what you want

— a "Reservoil" standard sized bearing. It makes life so much easier for you. It is made of sintered-metal and incorporates its own lubrication. You can fit it wherever inaccessibility would make lubrication difficult — or whenever you know the user is not going to bother much about servicing. The sintered-metal of Reservoil bearings is impregnated with oil which is fed by capillary action direct to the bearing surface. No oil runs to waste and no maintenance is necessary.

...you should specify *Reservoil*

Sintered-Metal OIL RETAINING **BEARINGS**

There are shapes and sizes of "Reservoil" bearings for every normal medium duty, but special attention is drawn to the large range of plain cylindrical bearings to B.S.I. standard dimensions. Most sizes are held in stock.

Please write or 'phone for Technical Brochure SD.40 or Catalogue of sizes SD.58

THE MORGAN CRUCIBLE CO. LTD. WANDSWORTH WORKS, POINT PLEASANT, LONDON, S.W.18

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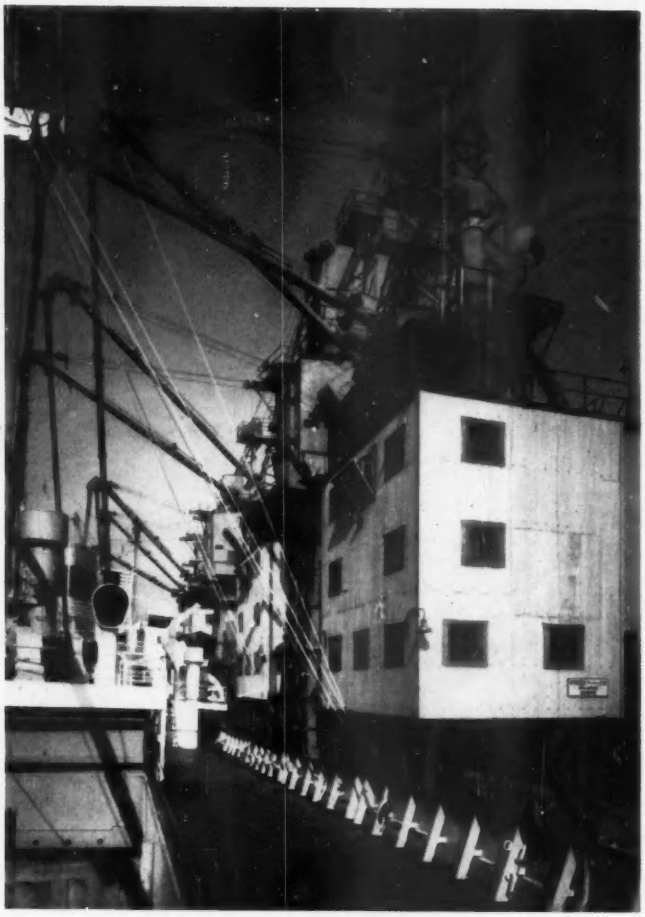
here today gone tomorrow



Spencer Pneumatic Elevators are playing a vital part in the speedy turn-round of ships in ports, unloading grain cargoes at rates up to 600 tons an hour.

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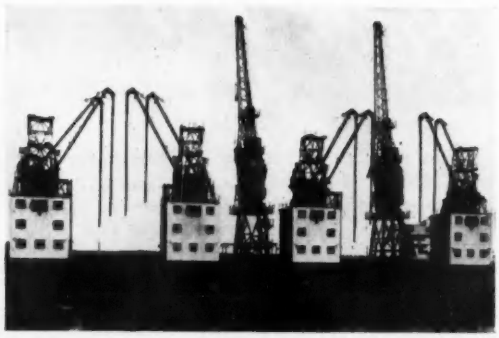

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MELKSHAM - WILTSHIRE

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Holroyds help you to keep the wheels turning by holding on call for immediate delivery worm reducers in no less than 340 combinations of size, ratio and type.

Holroyd HU	Single reduction underdriven with horizontal input and output shafts. Centre distances 3, 4, 5, 6, 7, 8, 9, 10 and 12 inches.
Holroyd HO	Single reduction overdriven with horizontal input and output shafts. Centre distances 3, 4, 5, 6, 7, 8, 9, 10 and 12 inches.
Holroyd HV	Single reduction with vertical output shaft and horizontal input. Centre distances 3, 4, 5, 6, 7, 8, 9, 10 and 12 inches.
Holroyd Verso	2½ inch centre distance. Suitable for underdriven, overdriven or side mounting.
Holroyd F	Made in three sizes—1½, 1¾ and 2½ inch centre distance, and suitable for a variety of mounting positions.
All the above are available with any of the following ratios:—5, 7½, 10, 15, 20, 25, 30, 40, 50, 60 and 70 to 1.	

In addition to these gear boxes constantly held in stock, there are other types and sizes (up to 24 inch centre distance) most of which can be built up for you fairly quickly.
Send for the 50 page book about Holroyd worm speed reducers and you will always have complete details of the whole range by you for quick reference.

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90 YEARS OF GEARS

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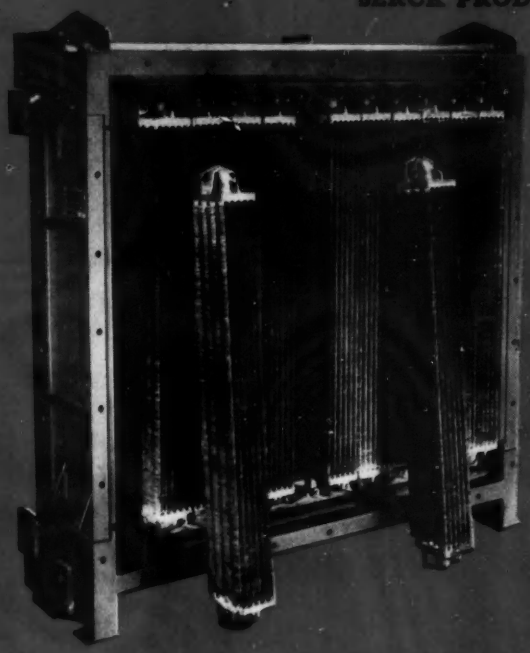

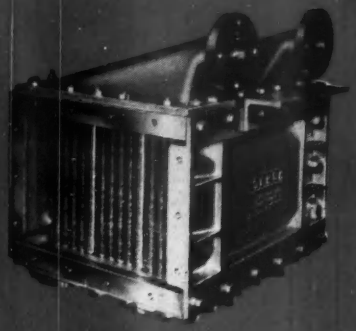

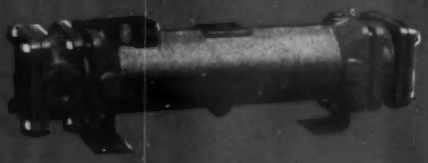

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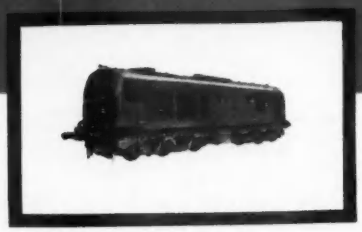

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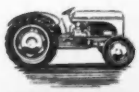
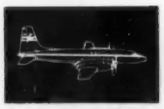
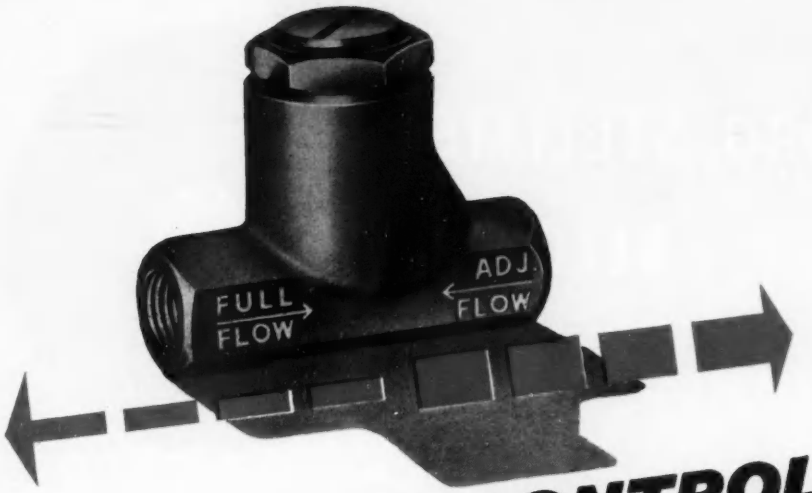
COOLING EQUIPMENT

* **Sectional Radiators**
* **Charge Air Coolers**
* **Lubricating and Transmission Oil Coolers**





SERCK RADIATORS LTD. **SERCK TUBES LTD.** **Birmingham 11**



FLOW CONTROL

SCHRADER FLOW CONTROL VALVES provide a control of movement speed so essential to the effective use of compressed air equipment. The range of valves has now been extended to give even greater flexibility.

The valve is easily set, by means of an adjustment screw, thus determining how fast the air flows in the "adjusted" direction. If used in conjunction with an air cylinder, for instance, the valve can control the pressure build-up and with it the *speed* of the piston thrust, but not its pushing force. This controlled thrust speed avoids the impact shock of suddenly applied air pressure, yet permits full thrust force. When the valve is operating in the "full flow" direction a poppet is opened, giving open line pressure. Where controlled air flow is required in both directions, two valves can be fitted back-to-back.

Although designed primarily for air control, these valves are equally suitable for use with oil or water in hydraulic systems.

Body of cast brass.
Non-corrodible plunger assembly, replaceable in one unit.
Substantial lock-nut resists vibration.

The $\frac{1}{8}$" bore valve is the latest addition to the Schrader range, which now covers $\frac{1}{8}$", $\frac{1}{4}$" and $\frac{3}{8}$" B.S.P. sizes. These provide a pressure range as follows :— AIR : 0-400 P.S.I. OIL or WATER : 0-800 P.S.I.

Schrader

FLOW CONTROL VALVES

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To: **A. SCHRADER'S SON,** Air Control Products Dept. ED, **829 TYBURN ROAD, ERDINGTON, BIRMINGHAM, 24**
Please send details of Schrader Flow Control Valves

NAME.....

ADDRESS.....

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Stellite X40
Alloy vanes in Napier
'Eland' nozzle guide assembly

The resistance to destruction of Deloro Stellite Alloys is worth investigating. Heat, abrasion and corrosion resistance is of a high order. Even combinations of these destructive effects make little impression on these remarkable alloys.

● ***Send for publication SP13 which gives properties of some of the alloys in the wide range.***

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Drop Forgings
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since the first Whittle engine,
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A 16mm Colour Film with sound commentary, entitled 'Drop Forgings in Alloy Steels,' is available on request.

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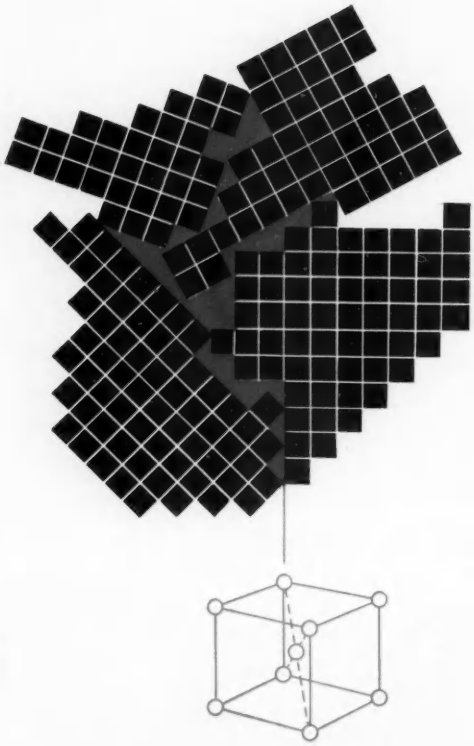
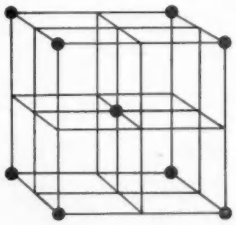
GRAIN CONTROL

Seen under a microscope, BRYMILL tested steel (A) shows a greater area of Atomic Disarray than do many of the coarser grades (B).

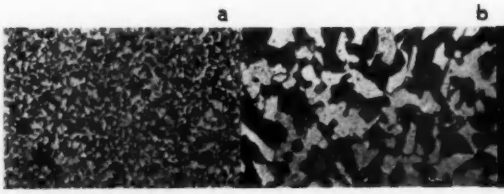
This difference is due to the technique of 'Grain Control' which ensures a tougher product, possessing lower internal stress and capable of withstanding rigorous uses in all conditions.

BRYMILL Laboratories will be happy to advise on the grades of steel most suited to your particular need.





a b



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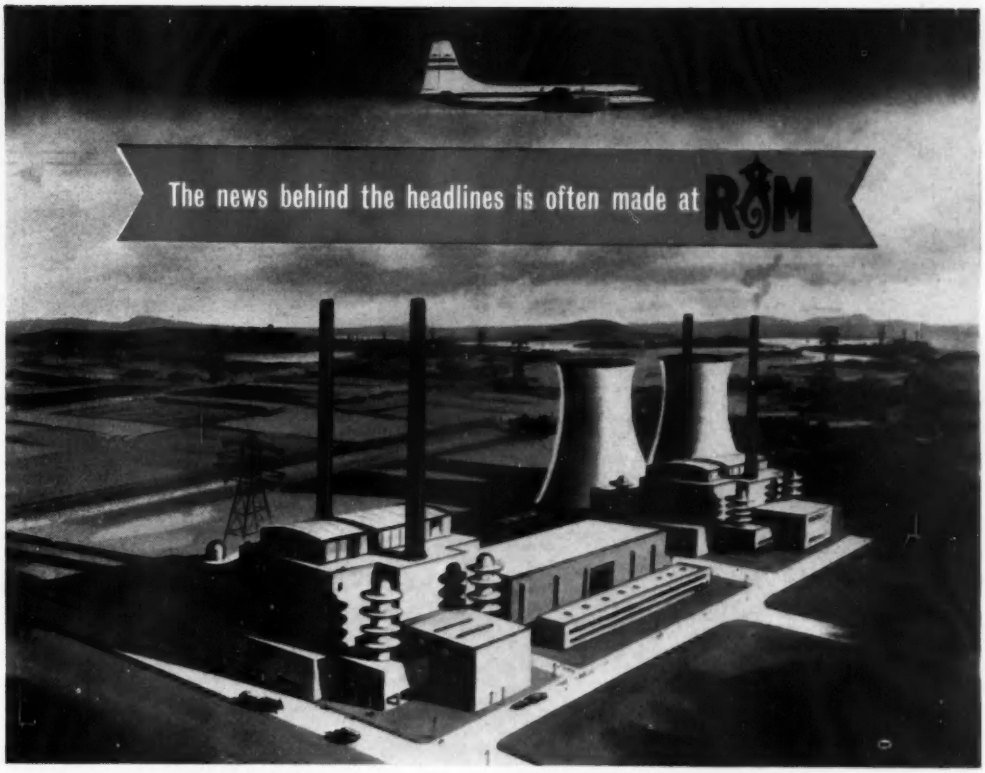
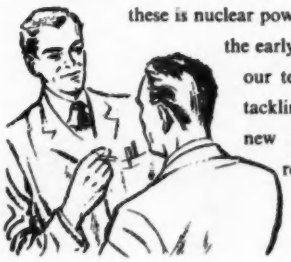


Have Ransome and Marles been associated with any of the big developments in British industry?

We don't hit the headlines — but we often help to make headline news possible. Since the war we have carried out research into design, materials, lubrication and production for a number of important projects. One of these is nuclear power generation. From the early days of Calder Hall our technicians have been tackling fresh problems as new and more powerful reactors are designed.



Are there any other interesting projects?

Yes, several. Britain has been achieving a world-wide success with her aircraft engines. Two notable users of R&M Bearings are Armstrong-Siddeley Motors and Bristol Aero Engines. The Proteus engines of the latest Bristol Britannia are of course fitted with R&M Bearings.

Then again "automation" is a popular word these days. We at R&M are becoming increasingly "automatic" in many of our processes in shops and offices. We also supply the bearings for the latest electronic machines. Our customers include Powers Samas, Elliott Brothers, IBM and British Tabulating Machines — just another example of the role played by R&M in all fields of industrial development.

BALL & ROLLER R&M BEARINGS

RANSOME & MARLES BEARING CO LTD • NEWARK-ON-TRENT • ENGLAND

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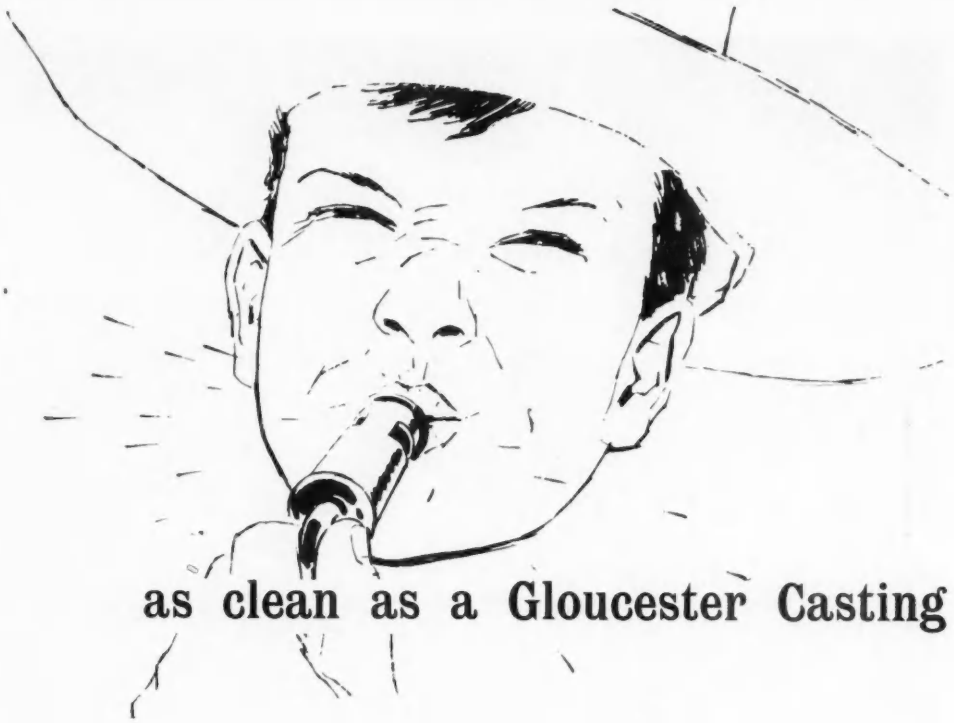

as clean as a Gloucester Casting

Brake shoe for small vehicle in Malleable Iron.

Bearing bracket in Malleable Iron. Weight 3½lbs

"As clean as a Gloucester Casting" means that Gloucester malleable iron castings are of high definition, true to pattern, cleaner and smoother because of better sand practice and better fettling.
Mould and core sands and their bonding additives are under constant laboratory supervision, even the very sand grains are sized and numbered, and consistency and distribution of sand are strictly controlled by a continuous mechanical unit. The high refractory characteristics prevent sand "burn-on" at re-entrant angles, thus greatly increasing the life of cutting tools during the machining process.
The new elevator-type electric furnace anneals in 48 hours! —instead of the usual 7 days. It also allows greater control of the component during annealing, resulting in uniformity of metal, greater strength, and resistance to impact.

A typical Gloucester Malleable specification.

Gloucester Blackheart Malleable		*Gloucester Lamellar Pearlitic Malleable*	
Elongation ..	18%	Elongation ..	5%
Yield Point ..	12 tons	Yield Point ..	24 tons
Tensile Strength	25 tons psi	Tensile Strength	35 tons psi

GLOUCESTER
THE HOME OF GOOD CASTINGS

GLOUCESTER

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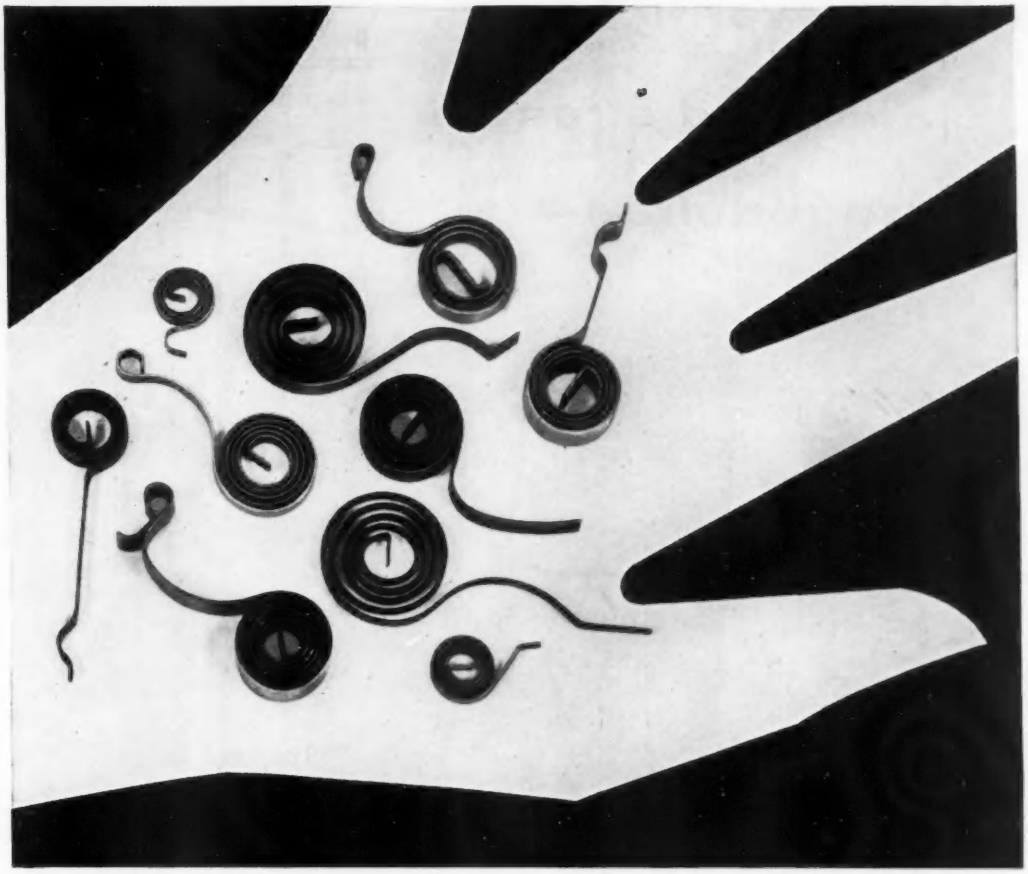
(A subsidiary of the Gloucester Railway Carriage & Wagon Co. Ltd.)



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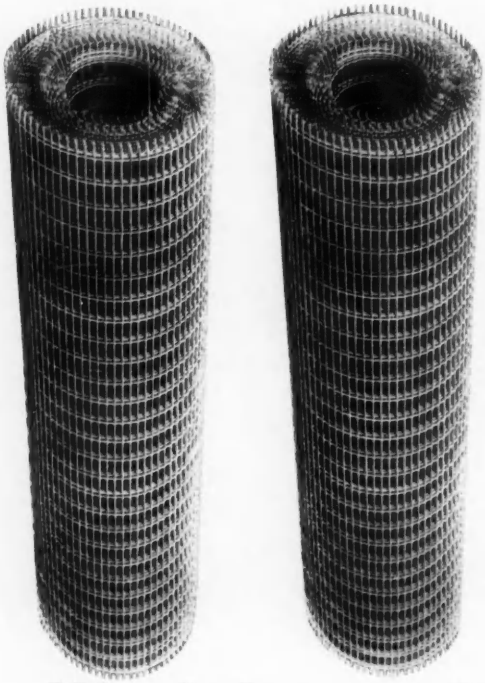
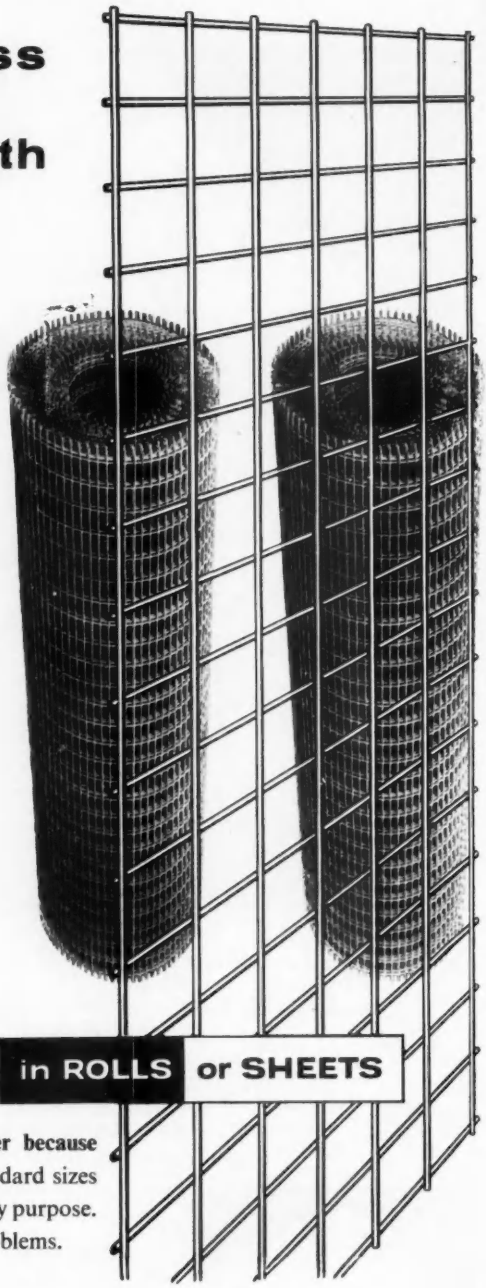
Wherever lightness and strength are required—





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in ROLLS or SHEETS

Cut it to the shape you want—it holds together because it's welded together. In the Weldmesh list of standard sizes you will find a mesh size and wire gauge to suit every purpose. A technical service is available to handle any problems.

Weldmesh is a registered trade name and is supplied direct to users by the sole manufacturers:

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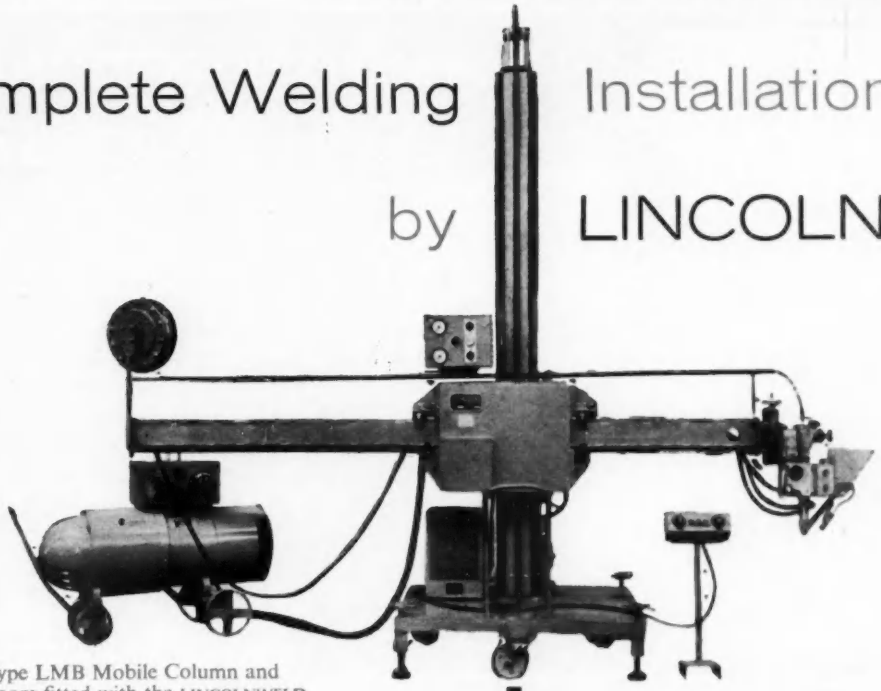
Export Sales: 54 Grosvenor Street, London W.1

M-W.896

Complete Welding Installations by LINCOLN



Type LMB Mobile Column and Boom fitted with the LINCOLNWELD B.10 Fully Automatic Welding Head.

Whether for hand or automatic welding applications, LINCOLN can offer a complete range of arc welding equipment and work handling fixtures to suit your individual requirements. Typical examples of our latest positioning equipment are shown here, but for full details and specifications of the various types available, please write today to:

Type LSAR 400 Self-Aligning Rotator.

Type LVH Variable Speed Positioner.

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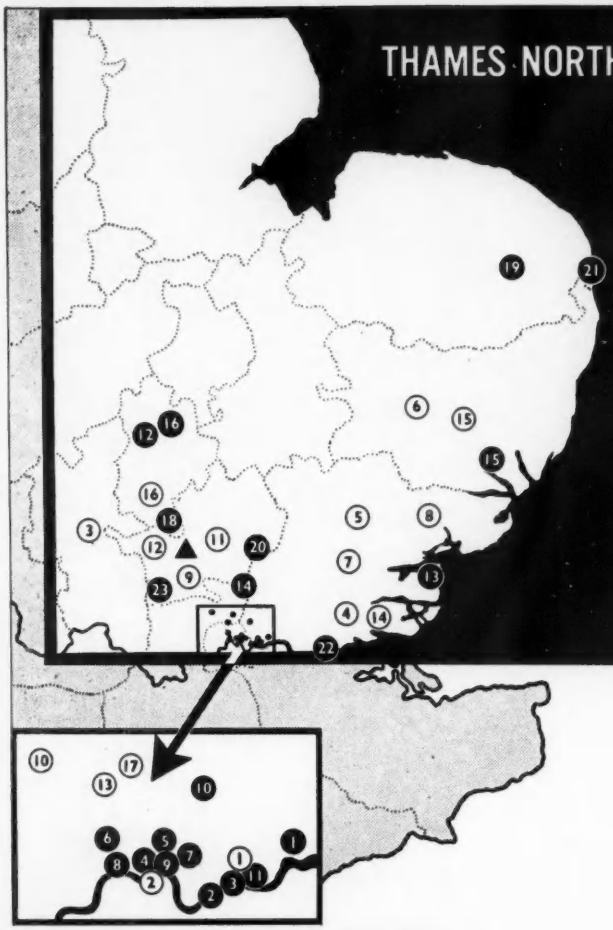
WELWYN GARDEN CITY · HERTFORDSHIRE
WELWYN GARDEN 920 (5 lines) 4581 (5 lines)
Cables & Grams: Shield-Arc, Welwyn Garden City

P.1a

THE BRITISH ELECTRICITY GRID UNDER CONTROL



THAMES NORTH GRID CONTROL AREA

installed by S.T.C. as the centralised control and indication centre for the Eastern Division and part of the London Division of the British Central Electricity Generating Board. By a new 'standardised system' of control, the operation of the Power Stations, and Switching Centres in the Counties of London, Essex, Suffolk, Norfolk, Herts, Bucks and Beds is efficiently supervised and controlled to supply Power to a population of approximately 7 million people.

▲ THAMES NORTH CONTROL CENTRE

●	GENERATING STATIONS	○	SWITCHING STATIONS ETC.
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G1	Barking	S1	East Ham
G2	Blackwall Point	S2	Finsbury
G3	Brunswick Wharf		EASTERN
G4	Grove Road	S3	Aylesbury
G5	Hackney	S4	Basildon
G6	Islington	S5	Braintree
G7	Poplar	S6	Bury St. Edmunds
G8	St. Pancras	S7	Chelmsford
G9	Stepney	S8	Colchester
G10	Walthamstow	S9	Elstree
G11	West Ham	S10	Finchley
	EASTERN	S11	Hatfield
G12	Bedford	S12	Hemel Hempstead
G13	Bradwell	S13	Hornsey
G14	Brimsdown	S14	Rayleigh
G15	Cliff Quay	S15	Stowmarket
G16	Goldington	S16	Sundon
G17	Letchworth	S17	Tottenham
G18	Luton		
G19	Norwich		
G20	Rye House		
G21	South Denes		
G22	Tilbury		
G23	Watford		

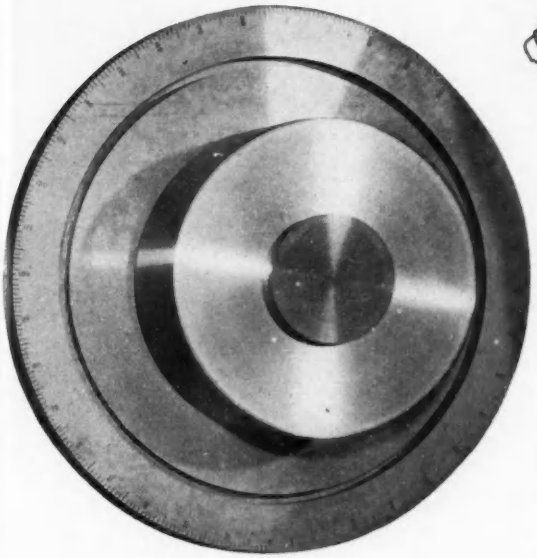
Thames North Control Room

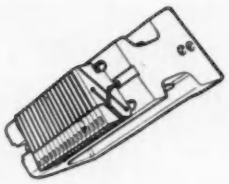
Thames North Control Centre is one of the three control centres installed by S.T.C. for the Thames North, Leeds and Newcastle Control areas in the Central Electricity Generating Boards electricity supply system. This system with its national centre and seven local control centres is the largest system under unified control in the world, having 260 Power Stations and a total output of 24,000 MW. The new "standardised system" of control, general indicating, telephone and telemetering equipment has been developed jointly by the Generating Board and the three telephone manufacturers — Automatic Telephone and Electric Co. Ltd., the General Electric Co. Ltd., and Standard Telephones and Cables Ltd. In addition to the above schemes S.T.C has played an important part in the remote control schemes for the North of Scotland Hydro Electric Board (NOSHEB), Snowy Mountain (Australia), Owen Falls (Uganda,) Waipori (New Zealand), Aswan (Egypt) and Kariba (Rhodesia).

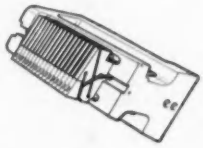
Standard Telephones and Cables Limited

Registered Office : Connaught House, Aldwych, London, W.C.2

TELEPHONE DIVISION: OAKLEIGH ROAD · NEW SOUTHGATE · LONDON N.11







Magnetic Storage Drum

for Computers and Data Processing

Originally designed to meet the stringent requirements of Automatic Telephone & Electric Co. Ltd., for telecommunication application, the A. T. & E./Sperry Magnetic Storage Drum was developed in collaboration between the two companies. It is now available for computer and data processing systems, for which it is the most advanced component providing an economical high-density storage of information.

Special features include an extremely long running life and automatic lubrication system, a nickel-plated recording surface to enable transistorised or valve circuits to be employed and the ability to position reading and writing heads both axially along the mounting posts and circumferentially throughout the full 360 deg. of the drum periphery by means of the continuous "T" slot.

Two versions of the A. T. & E./Sperry Drum are available at present, both 9 inches in diameter; one with an effective surface area of 100 sq. in. and the other of 157 sq. in.

A wide range of electronic equipment complementary to this drum is available from the Automatic Telephone & Electric Co. Ltd.

ELECTRONIC COMPUTER EXHIBITION

OLYMPIA
Nov. 28 to Dec. 4
STAND 39

SPERRY GYROSCOPE COMPANY LIMITED

GREAT WEST ROAD BRENTFORD MIDDLESEX

(In collaboration with Automatic Telephone & Electric Co. Ltd.)

ASHMORE'S IRON CASTINGS

QUALITY AND SERVICE
ASHMORE'S IRON CASTINGS

Seven-cylinder diesel engine casing. Uniform strength throughout and shock and water pressure resistance are necessary for the successful use of this type of general engineering casting.

HIGH DUTY IRON AND GREY IRON CASTINGS

Printing machine cylinder and bearings.

Castings up to 20 tons are produced to meet specific requirements for heat, wear or corrosion resisting applications and conform to B.S.S. 1452, grades 10-26.

Moulds and cores by the CO_2 process, other methods include green sand, hand and machine moulding, loam moulding, oil sand, coremaking and sand slinger production.

ASHMORE, BENSON, PEASE & CO

(MEMBER OF THE POWER-GAS GROUP)

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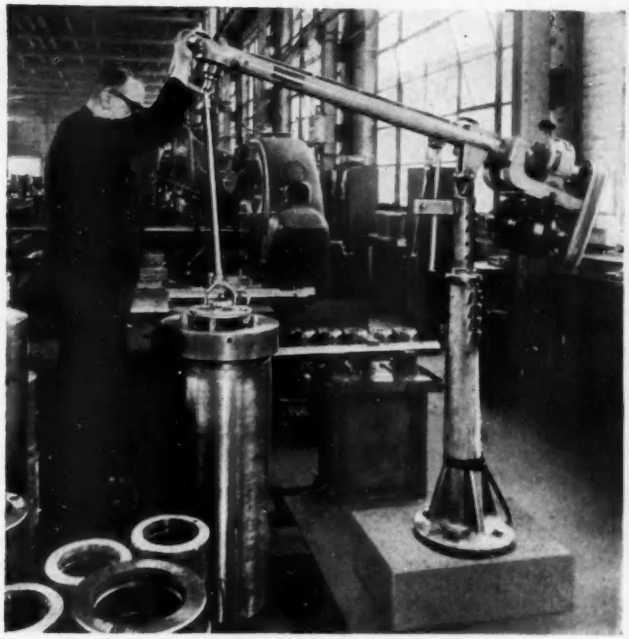

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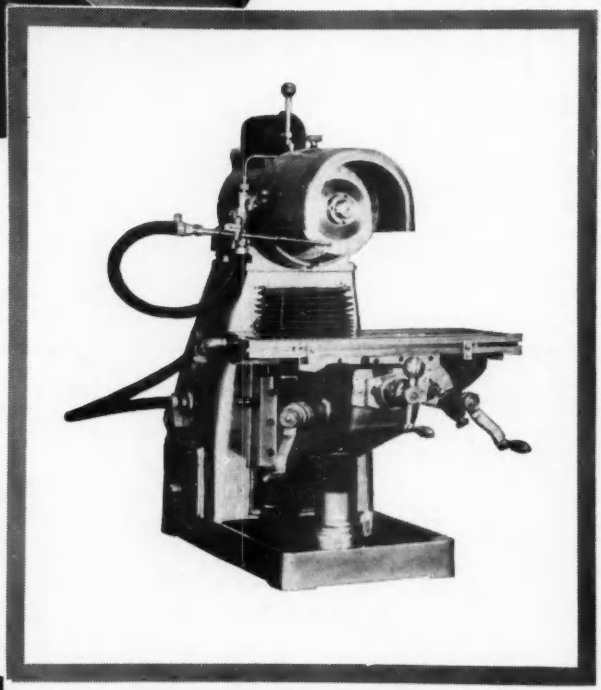

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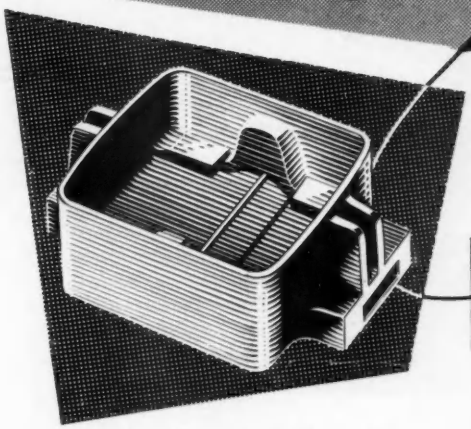

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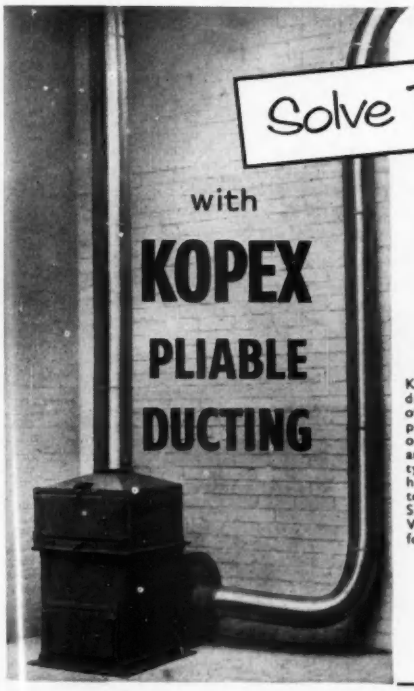

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *HARD OXIDE COATINGS FOR ALUMINIUM*

It is reported that over-machined aluminium parts can be reclaimed and other products improved by a new electrochemical finishing method which produces extremely tough oxide coatings of high dimensional accuracy. These coatings differ from conventional anodic finishes in two respects, i.e., they may have thicknesses in excess of 0·006 in., and they possess a ceramic structure which provides excellent resistance to abrasion. The coatings cost about 40% less than hard chrome plating and slightly more than conventional anodizing. It is stated that some parts are deliberately fabricated undersize to take advantage of the wear resistance of the new coating. Experience is said to have shown that, if such coatings are applied to aluminium pistons for racing-car engines, the pistons will be in good condition after forty races, whereas aluminium pistons are ordinarily replaced after every third race. Despite a wear resistance comparable with that of hardened tool steels, the coatings are not very brittle. They can also be used on forms for coils of electronic equipment, to which they will impart sufficient dielectric strength for insulation up to 4000 V. Because of their increased heat resistance, these coatings can withstand occasional flame impingement. Tests conducted to determine the relative ability of the coatings to prevent corrosion have shown that they resist more than 13,000 hours of salt spray, while anodic films of the conventional type can withstand no more than 250 hours. Before processing, the aluminium parts to be coated are cleaned and masked in the same way as for electroplating. They are then suspended in a stainless-steel tank containing a mixture of mineral and organic acids, the composition of which is not disclosed. The electrolyte is chilled to a temperature between 0 and 15°F by passing it through a refrigeration unit, in order to prevent it from attacking the parts to be coated.

● *PRODUCTION OF VERY FINE MINERAL POWDERS BY AN ELECTRIC ARC*

A new process has been devised for the production of mineral powders of a very fine grade, either by vaporizing mineral refractories or by volatilizing and burning metallic vapours. The process is carried out in two distinct stages in separate chambers, the first stage involving the volatilization of the raw material, and the second the combustion of the product obtained from the first stage. The first stage is effected in an enclosed electric-arc furnace, the output of which is controlled by introducing into the furnace an inert gas, the rate of flow of which is automatically controlled as a function of the intensity of the arc current. Depending on the nature of the material treated, the first stage may involve both the reduction and volatilization of the raw material. The arc furnace comprises a furnace hearth, a graphite canopy, and an outlet tube having a graphite sheath. The second stage incorporates a hood which covers an outlet for the vapours from the arc furnace and means for introducing an inert gas immediately after the opening of the vapour outlet into the hood. A combustion gas is introduced into the hood through one or more openings in a position after the inlet for the inert gas in the direction of vapour flow. Adjustable shutters control the opening or openings, and the gaseous stream, carrying in suspension the mineral dust resulting from the combustion, is discharged through a duct. The dust obtained is then collected and separated by any suitable means, e.g., cyclone separators and filters. As an example of the efficiency of the new process, it is stated that silica dust has been produced with a particle size ranging from 0·01 to 0·1 micron. These particles are amorphous and are in the form of small spheres. As such, they are particularly suitable for use as fillers for plastics and rubber, as compared with dispersed silica containing quartz splinters of a polygonal form (and therefore prejudicial to rubber) produced by other processes.

● *IRRADIATED COLLOIDAL COAL IN DIESEL FUEL*

Experiments now being carried out with colloidal suspensions of irradiated coal in diesel fuel are based on earlier observations to the effect that exposure of coal specimens to integrated fluxes of slightly over 2×10^{19} slow neutrons per cm^2 has led to noticeable changes in carbon content of the samples. The higher-rank coals, such as anthracite and low-volatile bituminous coal, have been found to lose carbon gradually during early stages of irradiation and then to show an increase in carbon content, most changes being of the order of about 2% carbon. In the case of humic acid, a linear increase in carbon was noted, this increase amount-

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ing to about 7%. Similar data have been accumulated relating irradiation with fixed carbon, volatile content, oxygen content, and B.T.U. values, and have been evaluated in an attempt to determine the radiochemical mechanisms responsible for the changes observed. In general, demethanation and decarboxylation appear to be the most likely mechanisms, but losses of methane and carbon dioxide do not necessarily occur simultaneously. Further studies have shown that, by irradiation, coal of 1 to 4 microns particle size is split, making it of the order of the same particle size as conventional petroleum fuels. It has also been found that, through the use of some catalysts, better particle size of the mix of coal with oil can be secured, indicating that the coal is going into solution. Generally speaking, the theory is that coal is composed of saturated and unsaturated hydrocarbons, heterocyclic compounds containing oxygen, nitrogen, sulphur, and aromatic compounds, the latter being the primary constituents. In general, irradiation will cause degradation of the constituents of coal, resulting in turn in a decreased particle size, of the order of magnitude of 0·5 to 1 micron.

● *EXTRUDED MOLYBDENUM TUBING*

It is reported that arc-cast molybdenum, which has long been classified as virtually unworkable by conventional methods, can be handled with less difficulty if its grain structure is refined. Tubing in diameters ranging from 1 to 6 in. has been produced by a cold extrusion method, and seamless tubes, 12 in. in diameter and several feet in length, may be produced by special techniques. Lengths over 5 ft are feasible, depending upon the combination of dimensions (outside diameter and wall thickness). However, only unalloyed molybdenum has been successfully cold-extruded, because hard alloys such as molybdenum with 0·5% titanium cause excessive tool loads. Other shapes can be made if they are hollow, with one end closed, or where relatively heavy outside or inside diameter ribs are specified. The solid round billet for cold extrusion is made from the original casting by hot extrusion and hot rolling. The cast billets are first surface-conditioned by machining and heating in a salt bath at 2200 to 2400°F, the bath preventing both the fuming oxide and the formation of the slippery oxide surface characteristic of molybdenum, while the salt adheres to the surface and protects it while lubricants are applied. Extrusion ratios are about 3 to 1, and the extruded parts are stress-relieved by annealing. Cold work on the hot-formed product must be carried out above the brittle transition temperature, i.e., above 150 to 200°F. Finishing operations often require intermediate anneals. In making tubes, the slug made by breakdown is heated to 600 to 800°F and cupped by backward extrusion, the tools being preheated to 500°F. The bottom of the cup must be trepanned or bored out before forward extrusion. It is reported that attempts are being made to make tubing with a small wall thickness. Tooling failures and breakage still present problems, but tubes with 0·018- to 0·03-in. wall thickness have already been formed.

● *ELECTRIC TRANSDUCER UTILIZING THE HALL EFFECT*

A recent proposal is concerned with a transducer for the conversion of small mechanical movements into corresponding electrical signals by making use principally of the Hall effect in a semiconductor, i.e., the development of an electromotive force in the semiconductor transverse to the direction of a current flowing through it whilst it is subjected to an externally applied magnetic field at right angles to the direction of current flow. In addition to, or instead of, the Hall effect, the transducer action can be obtained by utilizing the change in the resistance of the semiconductor with changes in an applied magnetic field. The transducer comprises a piece of indium antimonide provided with leads for passing an electric current through it. A non-uniform magnetic field is provided at the semiconductor, either by using specially shaped magnet pole-pieces or by placing part of the semiconductor outside the magnet gap. Either the magnet or the semiconductor is made movable, so that the changes in the magnetic field strength caused by the relative movement of magnet and semiconductor produce changes in the current flowing in the semiconductor, causing signal currents. When the external leads by which these signal currents are taken off are positioned transversely to those by which the external current is fed in, the resulting signals are due to the Hall effect. If the signal currents are taken off in series with the external current flow, the signals are the result of magneto-resistance effects in the semiconductor. As indium antimonide shows a large Hall effect, it is stated to be especially suitable for use in this novel electric transducer, a particular application of which is in a microphone ; it can, however, also be employed in vibration pick-ups, strain-gauges, and similar equipment.

● *FOIL-CLAD LAMINATES IN PRINTED CIRCUITRY*

A printed circuit may contain components, such as inductors, capacitors, or resistors, or it may consist solely of printed wiring which provides point-to-point electrical connections or shielding. In the manufacture of foil-clad laminates used for printed circuits, the foil, coated with a thermosetting adhesive, is bonded to

'achieves
the board's
objective
of offsetting
increasing costs by
greater
efficiency . . . '

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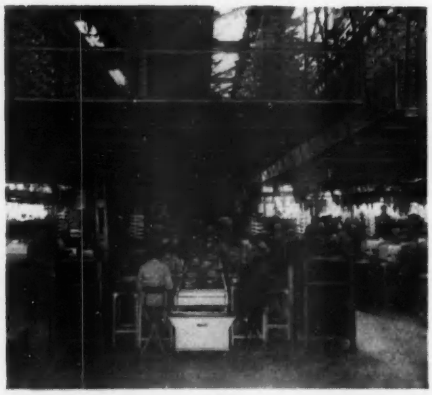

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sheets of resin-impregnated fibrous filler, such as paper, fabric, or mat. According to a recent article describing American practice, electrolytic copper foil, either 0·00135 in. or 0·0027 in. thick, is normally used and is made in widths up to 60 in. by continuous electrodeposition from a copper sulphate plating bath onto a slowly revolving lead drum. Aluminium and silver are the only other available foils having sufficient conductivity to be of interest electrically, but the cost of silver and the difficulty of soldering aluminium eliminate them from consideration at present. Inasmuch as printed wiring is supported on the surface of the insulator, electrical leakage is far more serious than with point-to-point wiring, where leakage can occur only at terminals. Contamination, both in processing and in service, becomes a problem, since residues of etchant and solder flux, fingerprints, and even airborne dirt can induce insulation failures. It is a characteristic of the process that a film of adhesive remains on the surface of the boards, so that the adhesive must be a good insulator, as well as a good bonding agent. Uniformity and continuity of the foil are of course essential, and shortcomings in this respect still present some difficulty. Nevertheless, although trends may eventually develop away from etched-foil processes, it seems probable that the etching of copper foil-clad laminates, because of their simplicity and adaptability to change, will occupy an important position, particularly in the development stages of circuit design and in the manufacture of items in limited demand.

● *CHARACTERISTICS OF COMPENSATED GAS BEARINGS*

The trend towards higher speeds and higher temperatures has created a major design problem in the support of shafts and other moving elements in airborne equipment. Conventional bearings, such as oil-hydrodynamic and rolling-contact types, are currently operated near their ultimate limits of speed and temperature. Although the compensated gas-lubricated bearing offers one attractive solution to this problem, little information has been published which would enable designers to compute reliably the load capacity, power loss, or dynamic characteristics of such bearings. Even qualitative effects of various design parameters on the dynamic characteristics of a given bearing configuration cannot be deduced in many instances. Functionally, an almost direct analogy exists between a fluid bearing and a conventional hydraulic or pneumatic fluid-control system. A fluid bearing is essentially a position-control system which tries to hold a bearing journal centered in a bearing sleeve. This position device is subjected to disturbances in the form of loads which must be carried by the bearing elements, and a satisfactory bearing must have a load stiffness sufficient to keep deflection less than a prescribed fraction of the bearing clearance when the system is subjected to the maximum expected load force. A recent study of gas bearings deals with externally pressurized bearings in which any effects of shaft rotation on static or dynamic characteristics can be neglected. The problem has been simplified to the point where analysis can be used to yield quantitative design information, and the results obtained can be used to compute the effects of various design parameters on bearing performance.

● *POLYPROPYLENE PLASTIC*

The new plastic polypropylene, produced by the Ziegler process of polymerizing ethylene with the use of organo-metallic catalysts, can be formed without difficulty into injection-moulded parts, extruded shapes and tubes, extruded films, and drawn sheet, as well as into mono- or multi-filaments. Moreover, it is the first hydrocarbon polymer which is completely resistant to stress-cracking, and yields parts of high gloss and excellent chemical resistance. From comparative data it is apparent that a valuable new material has become available for the fabrication of a great variety of industrial items. In volume per unit weight, polypropylene offers the most favourable ratio of any plastic material. Thus, any formed part will possess an extremely high strength-to-weight ratio, while the tensile strength and elongation are adequate, as are also tensile modulus, yield stress, and yield strain. Its notched Izod impact strength of 1 ft-lb per inch of notch is, however, lower than that of amorphous polymers such as cellulose acetate butyrate, though oriented items such as film and filaments are high in impact resistance, even at temperatures as low as −50°C. Flexural strength is excellent, being superior to that of most available plastics. With regard to stiffness, actual tests have indicated that the material is satisfactory for items such as tubing and vacuum-formed containers. The hardness, which amounts to 92 on the Rockwell R scale, is said to be excellent and is sufficient for all but the most severe requirements. Polypropylene has a crystalline melting point of approximately 165 to 170°C, this property being manifested by a high degree of heat resistance. Also, like all polyolefines, it has substantially zero water absorption.

● *REMOTE FLUOROSCOPY IN THE 2-MeV RANGE*

While industrial radiography in the 1- to 2-MeV range is now a routine procedure, and exhaustive studies have been made in the field of 1-MeV fluorography, fluoroscopy in this range has never been seriously attempted, the main reason being the problem of ensuring sufficient

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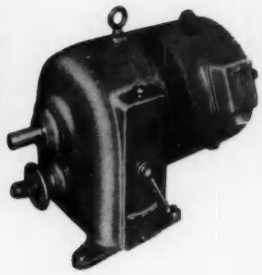

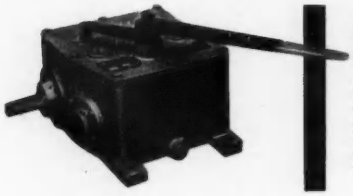

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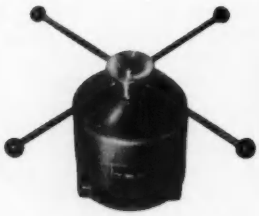

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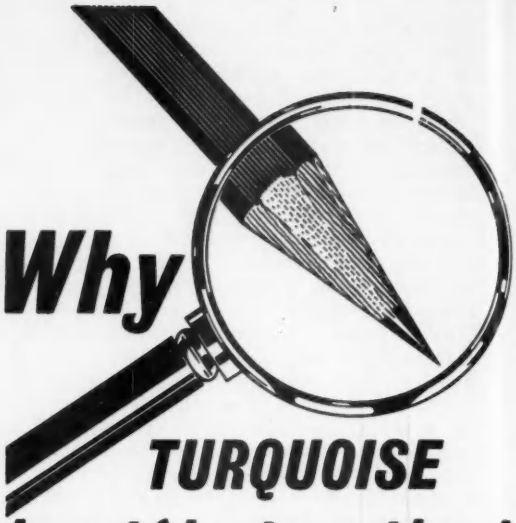

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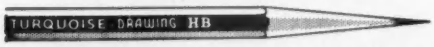

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protection against radiation. The performance of a closed-circuit television system below 250 kVp has been reported some time ago in the literature. A recent report now discusses the usefulness of a closed-circuit television system in the 2-MeV range and points to additional fields of application. The source of radiation used in these investigations was a 2-MeV Van de Graaff X-ray generator producing 75 roentgens per minute at 1 metre. The focal spot of 1 mm diameter was small enough to justify neglecting the calculation of minimum perceptible effect with the geometry used. The high radiation dosage delivered by the generator has a favourable effect on the resolution of the television system, since resolution is a function of screen brightness. A closed-circuit television system with 1029 scanning lines and low-noise high-gain amplifiers was used. The system itself comprised a detector unit, with the fluoroscopic screen, lens, television pick-up tube and input amplifiers, and a remote viewing console incorporating drive units, pulse former, and amplifiers, as well as a 10-in. kinescope viewing unit. A " wide-spaced " image Orthicon and a semi-persistence kinescope tube were used for penetrameter investigations, while a short-persistence kinescope was used for fluoroscopic-screen brightness measurements. With a kinescope viewing screen of 10 × 10 in., the optimum television-system resolution occurs when the vertical and horizontal line resolutions are approximately equal.

● *IRON-ALUMINIUM ALLOYS WITH STAINLESS-STEEL PROPERTIES*

The most striking characteristic of Fe-Al base alloys is their resistance to high-temperature oxidation, which can be made to exceed that of any stainless steel. The use of binary Fe-Al alloys has, however, been limited by their room-temperature brittleness. As the authors of a recent report point out, it is believed that the factors responsible are (1) the appreciable difference between the ion diameters and crystal structures of iron and aluminium; (2) the tendency of an Fe_3Al type towards an ordered structure in alloys containing 13 to 21% Al ; (3) an apparent sensitivity of these materials to the effects of interstitially dissolved elements ; and (4) a considerable bent towards grain growth at high temperatures. A second inherent deficiency of binary alloys is their moderate high-temperature strength. Aluminium additions tend to prevent allotropic transformation in iron, and Fe-Al base alloys retain a body-centered structure at all temperatures. The inclination to grain growth makes the Fe-Al alloys hard to weld. The weld zone is usually a coarse, columnar structure when Fe-Al filler metal is used. The use of an austenitic filler metal results in a ductile deposit, but the heat-affected zone next to the weld becomes brittle. The undesirable properties of the Fe-Al alloys can, however, be rectified by adding a sizeable amount of chromium, which has been found to eliminate the super-lattice as a source of difficulty and to confer corrosion resistance. Two experimental alloys have recently been developed. The first of these, containing 5·5% Al and 9·5% Cr, appears to have properties comparable with those of type-430 stainless steel. The second alloy contains 7·5% Al and 5% Cr, as well as small additions of other elements. Its oxidation resistance is stated to be exceptional and comparable with that of type-347 stainless steel. Neither of the two alloys can successfully be fusion-welded, but resistance welding is possible.

● *EFFECT OF SHOT-BLASTING ON THE CORROSION FATIGUE OF MILD STEEL*

Shot-blasting is in general use in the shipbuilding industry to remove mill-scale from steel plates and to make the paint adhere to their surfaces. The shot-blasting process work-hardens the surface layers of the plate and, as a result, its mechanical properties are influenced, particularly fatigue strength being considerably improved. A recent Japanese investigation is concerned with the fatigue properties of as-rolled and shot-blasted mild-steel plates in air, in water, and also when subjected to cathodic protection. It has been found that the shot-blasted plates had a tensile strength and fatigue limit which were 20% higher than the values obtained with plates in the as-rolled condition, while Vickers hardness was improved by about 25%. In the case of corrosion fatigue produced by the combined action of reversed stress and corrosion at the bottom of a sharp notch, where the stress is intensified, it was found that, when the stress is tensile, the potential is displaced in the anodic direction, and the corrosion products formed a the bottom of the notch are pushed out by the subsequent compression stress. The notch therefore gradually increases in depth and finally causes rupture of the material. As local sharpness is the decisive factor, differences in general surface irregularities have little effect on corrosion fatigue. In the fatigue tests on cathodically protected plates, the potential of each specimen was maintained throughout the test at between −0·80 and −0·85 V. This potential was a mean value for the specimens, and some local parts were presumably above the potential proper required for corrosion protection. The fatigue limits under cathodic protection were found to be considerably lower than those in air. It is concluded that the cathodic current must be increased to prevent corrosion of the inside of the minute notches, and it can then be expected that fatigue strength will rise above the values found in the case of exposure to air.

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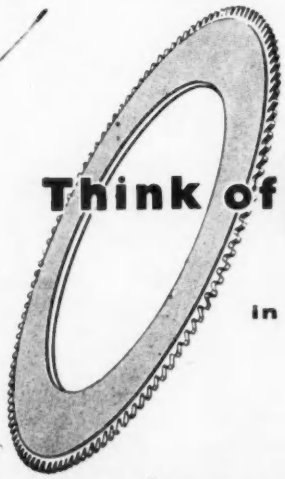

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Metallic Constructional Materials for the Chemical and Allied Industries

By S. ROWDEN, A.I.M., G.I.W. *

INDUSTRIAL and chemical plants are nowadays making more and more exacting demands on available metals, and, as a result of process divergencies, particularly in the case of chemical plants, design and fabrication are of the utmost importance for ensuring a reasonably long service life.

In addition, the comparatively recent development of new processes has obliged consideration of the merits of relatively new materials, and, while it is true that the combined efforts of metallurgists, design engineers, and metal producers generally have led to an extensive range of new materials, two major factors regarding the constructional aspects of such materials must be considered, these being corrosion resistance and ease of fabrication. Admittedly, pressure considerations are an extremely important, if not the governing, factor when discussing plant requirements, but fortunately the development of metallic materials has more than maintained the pace and standards set in this direction. In this article, therefore, it is proposed to examine materials only from considerations of corrosion resistance and ease of fabrication.

Before examining the materials available, however, it is worth while analysing the factors affecting choice of materials, with specific reference to corrosion resistance and weldability. Strictly speaking, there is no such material as a " corrosion-resistant " alloy, since this resistance is relative to, and a direct function of, environment.

The final choice of material should be made bearing in mind certain basic principles, and although the following list is not intended to be complete, it should serve to act as a guide to the ultimate choice.

(1) Nature (acid or alkaline) and basic composition of the liquid or gaseous media.
(2) Temperature, concentration, and working pressures of the system.
(3) Trace elements or possible contaminants which may be present.
(4) Any possible oxidizing or reducing conditions, attempts to establish which should be made.

Other factors, such as degree of aeration, flow rate, and even the basic design of the vessel should be taken into consideration. Unfortunately, despite careful specification of the material, the user is not insured against anything more than an estimated corrosion resistance. The material selected is accepted and chosen in the light of the basic factors quoted, allied to which an estimated industrial knowledge of how similar alloys in service have behaved may be added.

Once the alloy has been selected, there may well remain the significant question as to whether it can be readily fabricated, without undue problems, particularly with regard to welding, shaping, and forging. It is not possible in this article to deal fully with those factors affecting the weldability of a metal, since they involve a precise knowledge of fundamental metallurgical characteristics. However, practically all metals and alloys may be joined by a suitable and appropriate method, with welding accounting for the greater proportion of these metallic materials.

The choice of a manual or an automatic fusion technique, or of an inert gas with a consumable electrode or of a straight fusion technique, depends on a number of factors, including workshop facilities, particularly with respect to post-heat treatment and automatic welding. Thus, consideration must be given to such questions as the ability of the weld to harden from the temperature of welding, the possibility of undue residual stresses, the production of homogeneous joints, and the ability of the weld to exhibit a strength proportional to, and possibly in excess of, that of the parent metal. Similarly, in the light of basic experience and technology, it may be necessary to make a decision regarding the pre- and post-heat-treatment of welds. These are all points worthy of consideration in deciding the most suitable method and technique for a specified project.

Thus, it can easily be appreciated that welding is a flexible process, and that fabrication by welding has brought about a minor revolution in this direction. When properly conducted, it serves as a highly efficient means of joining metals, and in certain instances may well be the only method of producing a reliable metal-to-metal joint.

MILD STEEL

Often termed the " Aunt Sally " of metals, and sometimes the most underrated material, mild steel accounts for an enormous percentage of fabricated components. Possessing excellent working and welding characteristics, it may be joined by almost any welding process. Economically, it is best welded by manual or automatic metallic arc methods when fabrication problems are kept to a premium.

Mild steel is widely employed in the construction of storage tanks, heat exchangers, vaporizers, and a variety of other jobs, an example of its use in 12-in. o.d. sludge pipes being shown in Fig. 1. Naturally, mild steel cannot be utilized for onerous corrosion duties, but it is worth noting that it has been used for storing sulphuric acid in concentrations of 80 to 98%.

Slight additions of alloying elements such as nickel, chromium, molybdenum, copper, and even arsenic, confer favourable properties on this material, either with respect to corrosion resistance, scaling resistance, or increased mechanical porperties. An example of the use of a low-alloy steel in the construction of a duct is shown in Fig. 2.

One unfortunate limitation of mild steel, however, is

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its low impact strength at sub-zero temperatures, and, where a high degree of notch ductility is required, other steels must be sought. To overcome the limitations of carbon-steel alloys, there is a host of linings, metallic and non-metallic, in everyday usage. Rubber, ceramics, non-ferrous alloys, sprayed metallics, and stainless steel are all used, generally with the mild-steel portion of the vessel designed to carry the working stresses.

Stainless-clad mild-steel vessels are not discussed in this section by virtue of the fact that, while it is true that the mild steel shell may be carrying the load, it is the stainless steel which forms the essence of the constructed vessel.

Although manual metallic arc methods are responsible for the great majority of fabricated mild steel, automatic and semi-automatic processes of welding are being increasingly used. Without detracting from the quality of a manually finished weld, automatic methods compare favourably with, and in some instances show a decided improvement over, manual methods.

Nickel and its Alloys

The metal-arc process is almost exclusively used in welding nickel and its alloys but, wherever thin sections require joining, it is not uncommon to use the argon-arc process. Undercutting tendencies on some inaccessible jobs have led to the use of an inert-gas process, even when fairly thick sections are to be joined.

Extraordinary care is needed during manipulation and fabrication of nickel materials and, since molten nickel shows a marked affinity for oxygen, filler wire in argon-arc processes should contain an element which exhibits the ability to de-oxidize the molten weld pool rapidly. A further injurious element to nickel alloys is sulphur, which is usually present in most paints, oils, and greases. It therefore becomes of paramount importance to uphold and maintain immaculate practices in shop procedure when fabricating nickel materials.

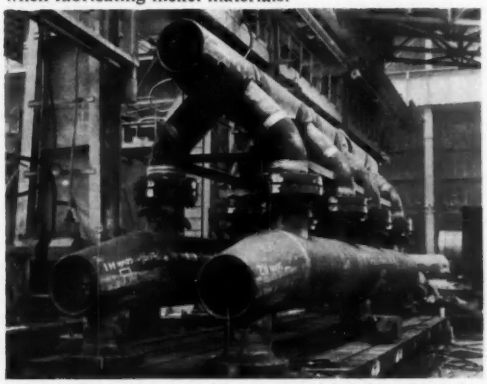

Fig. 1. Twin sludge pipes of 12 in. o.d., fabricated in mild steel.

The chemical industry has exposed nickel materials, with a notable degree of success, to acetic acid, formic acid, and formaldehyde, and in some instances to the conjoint action of these substances with sulphuric, sulphurous, and phosphoric acids.

Monel metal, which contains 70% nickel and 30% copper, is extensively used in tube pumps handling bromine trifluoride at elevated temperatures. In addition, this alloy exhibits excellent resistance to sea-water, even under aerated conditions. Caustic alkalis are rather corrosive agents, but most of the nickel alloys show good resistance, even with solutions up to 75% concentration.

Pure nickel has found extensive use in salt evaporators, an application in which most other materials would prove quite unsuitable. An example of the use of pure nickel in the construction of evaporators is shown in Fig. 3.

Where conditions are not too corrosive, progressive additions of copper to nickel provide a range of cupro-nickel alloys which exhibit fairly good corrosion resistance and mechanical properties. Inconel is another nickel alloy which possesses excellent resistance to specific environments ; for example, the pulp-paper industry employs this alloy for sulphite digesters.

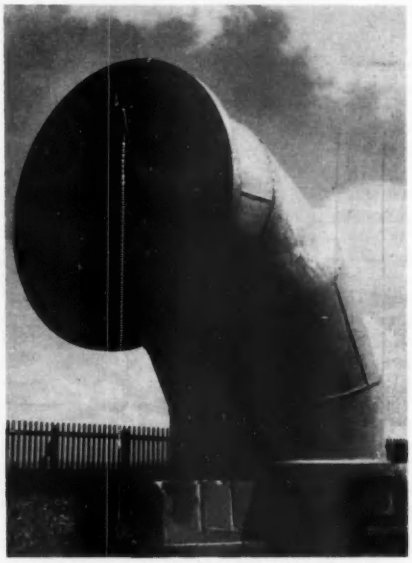

Fig. 2. Section of a duct fabricated in low-alloy steel.

Where sulphuric acid is produced, stored and handled, no single alloy can be guaranteed to withstand the range of fluctuations in temperature and concentration. For instance, in the manufacture of isopropyl alcohol, a variety of alloys is generally used, including Monel in the reboilers and vaporizer bundles, pumps, and ancillary equipment.

The problem of corrosion in petroleum refining is of a complex nature, and in some instances is extremely serious. To combat these difficulties, especially in cracking-unit heaters, distillation columns, reactors, and settlers, nickel and its alloys are used. Quantitative information on the performance of such alloys as Inconel, Hastelloy, stainless steels, and Ni-Resist, show surprisingly good results when they have been located in pumps and valves and in hydrochloric acid alkylation plants.

Aluminium and its Alloys

For many years the full benefit of aluminium alloys was confined to chemical-plant activities, owing to fabrication difficulties. This does not mean that aluminium was not employed, but rather that its use was somewhat restricted. Metallurgists were well aware of the enormous potential of aluminium, with its inherently good corrosion resistance, allied with strength and lightness.

To cater for the requirements of the process industries, a very wide range of aluminium alloys is now available,

the principal additives including copper, magnesium, zinc, and manganese, in different proportions, according to the degree of corrosion resistance and mechanical strength required. A high proportion of these more highly alloyed metals is susceptible to age-hardening, giving rise to increased ultimate tensile strength after some mode of heat treatment. The compatibility of aluminium alloys with corrosive environments and their capacity to withstand attack depend on the thick tenacious oxide film formed on the alloy.

Attention has been drawn to the fact that aluminium alloys are non-toxic and that they do not contribute to discoloration of end-products or catalyse sludge. The latter points are extremely important in the drug and chemical industries, where the quality of the product may be the prime consideration. Heat exchangers made of aluminium have been employed in ammonia synthesis plants, whilst the value of external electrical fittings in an ammonium nitrate plant brought about the elimination of previous shut-downs caused by corroded mild-steel fittings.

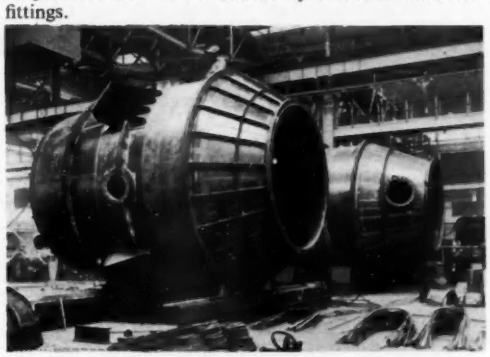

Fig. 3. Evaporators made of pure nickel.

As a result of numerous research programmes, it has been firmly established that aluminium and its alloys are highly resistant to concentrated white and red fuming nitric acid ; indeed, they have come to be regarded as the epitome of materials when such acids are under consideration. Even the copper-bearing aluminium alloys show marked resistance to inhibited fuming nitric acid.

The petroleum industry has had recourse, with notable success, to the use of aluminium alloys, an example being the long mileage of this material in the Karachi oil fields.

Two of the major factors deciding the use of aluminium materials for transportation purposes are probably the light weight and the purity of the transferred products. Thus, it is not uncommon to observe the wide use of this metal in portable bulk-liquid transportation, where their excellent resistance to impact and fatigue render the vessels extremely durable and safe.

In the fabrication of aluminium components, two distinct welding processes are used, one being the argon-arc process and the other an inert-gas metal-arc process. Without becoming too specific, it may be stated that, on the thinner classes of work, argon-arc welding is used, while the gas-shielded metal-arc process is reserved for alloy material greater than $\frac{1}{8}$ in. in thickness.

Stainless Steels

Stainless steels can be conveniently divided on a general basis into one of two groups, i.e., the ferritic and heat-treatable group and the fully austenitic group. The ferritic alloys may contain from 11 to 18% chromium, the largest class being the 13% chromium type, with the 18% type rather unusual. Austenitic stainless steels basically contain 18% chromium and 8% nickel, with the more corrosion- and heat-resistant steel containing up to 30% chromium.

The 18/8 steels are far simpler to weld than the 13% Cr steels, which rapidly air-harden from the temperature of welding, with the subsequent formation of hard brittle zones in and adjacent to a weld deposit where the electrode composition is similar to that of the parent plate. Chemical-plant manufacturers favour the use of an austenitic deposit for ferritic clad vessels, but in some instances post-heat-treatment of the finished vessel is a necessity. There are practically no limitations on actual welding processes, the most important restriction being the " active " gas-shield process, i.e., shielding by gaseous CO_2.

Stainless steels combine a host of advantageous features, including good scaling and corrosion resistance, acceptable strength at high and low temperatures, and the ability to exhibit a fine metallic lustre. This latter point is important in crystallizers, where pre-nucleation effects, which might be caused by surface roughness, should be kept to a minimum. Metallurgical control in the choice of steel, welding process, and specific subsequent heat-treatment can go a long way to mitigate the well-known problems of sigma brittleness, weld decay, " knife-line " attack, and crevice corrosion. Only by maintaining technical control and supervision during fabrication of these steels can welding hazards be overcome, ensuring a high quality of the finished product.

Chemical plants do not often use the martensitic type of alloys, which, however, have been extensively employed in power plant. It is also known that one specific grade of these alloys has shown resilience to the problem of pitting attack found in condenser tubes.

Ferritic stainless steels are used for handling nitric acid and also in those processes where corrosion is not a difficulty in itself, but where contamination of the final product must be avoided.

Despite the use made of these low-chromium steels, the greater proportion of stainless steels found in chemical and atomic-energy plants are of the austenitic type. Where conditions may prove too severe for a conventional austenitic steel, a molybdenum-bearing alloy may be selected. For instance, where acetic acid is encountered, molybdenum alloys have given prolonged service life and offer the most flexible range of usefulness in certain acetic acid process streams. Where the problem of acetic acid vapour arises, a more highly alloyed steel is generally called for.

Applications of stainless steels in sulphuric acid solutions have often led to complete failure. When galvanically coupled, either directly or electrolytically, conditions arise which are liable to render the stainless alloy passive or active, the latter almost certainly causing deterioration of the stainless steel. The variables governing the ultimate state of the steel may be a function of the oxygen content of the acid or contaminants present. The use of the molybdenum stainless steels confers marked improvements but, even so, the solution strengths handled should be restricted to the lower concentrations, e.g., up to 15%. All the austenitic alloys are accepted as being capable of withstanding the higher concentrations (80 to 95%) but, as pointed out previously, cast iron and mild steel have proved quite suitable for such concentrations. The intermediate range of sulphuric acid concentrations is the most difficult, showing a marked tendency to attack

most metallic systems ; even inhibition of the acid by a suitable oxidizing inhibitor has not entirely solved this problem. Alleviation has to some extent been achieved by copper-alloying a molybdenum-bearing austenitic stainless steel. Consequently, it appears a safe assumption that caution should be exercised and considerable discrimination used when selecting materials of construction for handling sulphuric acid. In environments where slight contamination by noble metal ions, such as copper, and where acid is only one liquid in an admixed solution, this becomes something of a necessity.

A spurious impression has been gained that stainless steels of the 18/8 type are worthy of consideration as materials for all caustic media. True, they have found, and are still finding, a place in chemical industries for specific types of caustic environments, but it is equally true that at relatively high temperatures strong alkalis tend to activate austenitic stainless steels. Under such conditions the passivity of the metal is destroyed, and its corrosion resistance may become comparable with that of mild steel. In general, it would appear that the stainless steels are fairly reliable in handling dilute alkaline solutions but, with strong caustic alkalis, other materials should be sought.

Under a variety of conditions and corrodents too numerous to mention in this article, stainless steels have shown satisfactory resistance to solutions of phosphoric acid, chromic acid, many organic acids, and ammonia solutions. Apparently, the corrosion resistance of stainless steel to phosphoric acid is subject to those minute factors not normally justified as worthy of consideration. For instance, two American corrosion scientists discovered the deleterious effects of halides and phosphorus oxides, when accelerated corrosion took place.

Copper and its Alloys

Since ancient times, copper and copper alloys have always been considered as corrosion-resistant metals. It is not surprising, therefore, to find that in tubular condensers, used extensively in refinery plants, copper alloys are widely employed. Initially, considerable difficulties due to dezincification (a selective chemical attack on one element in the alloy) somewhat hindered development but, once it was established that slight solid inhibition with arsenic or antimony overcame the problem, continued use was made of copper alloys.

Of latter years there has been a growing tendency to select tubes for corrosive conditions in cupro-nickel materials. Based on 70% copper and 30% nickel, they may be located in those parts of a plant which prove most trying with respect to corrosion.

Special mention has been made of tubes merely because this is perhaps the greatest outlet for copper materials in the chemical and allied industries. However, the alloys do find other uses, including equipment for industrial, chemical, and associated industries involving exposure to saline, alkaline, and acid solutions, for sea-water components such as shafting and general marine hardware, for earthing equipment subject to soil corrosion, and sometimes for fresh-water supply lines.

The commercial copper alloys cover a wide range of compositions, and some alloys may exhibit superior mechanical characteristics at the expense of their corrosion resistance.

The family of copper materials is fabricated by inert-gas welding, soldering, and brazing methods. Welding is generally carried out by the argon-arc process, but gas-welding techniques are also used, and it has now been shown that, with suitable precautions, a submerged-arc process may be utilized. It is hoped that in time this latter method will be applicable to the manufacture of high-quality welds satisfactory for specific code requirements.

Lead and its Alloys

Despite the antiquity of lead—it appears to be one of the earliest metals used in chemical engineering—new developments in lead materials are currently figuring in modern processes. The uses of lead are varied, with perhaps the greatest use made in handling sulphuric acid. A lead sulphate film formed on the lead is responsible for this corrosion resistance, but care should be exercised when lead is in close proximity to other metals, since the lead sulphate skin is cathodic to what are normally considered noble metals. Considerable lead equipment is utilized in the production of ammonia, of sulphuric, nitric, and phosphoric acids, and of nitrates, phosphates, and sulphates of ammonia.

Atomic-energy establishments have long appreciated the high absorption capacity of lead for β and γ rays. By virtue of its relatively high atomic number, lead is an excellent shielding material in X-ray work. Together with tungsten, lead is perhaps the most popular metal used for radiation shields, and a large proportion of portable isotope carriers used in site radiography is made of lead.

Lead welding, sometimes referred to as " lead burning ", fuses the joint together, the temperature of operation being considerably below that of conventional welding practices. No flux is used, but in certain instances there is a need to reinforce the joint by addition of further lead to one and a half times the thickness of the material being joined.

Other Materials

It is impossible in the scope of this article to embrace fully all materials used in chemical, ancillary, and other plants. However, it is worthwhile recording that, of the newer metals used, i.e., titanium, zirconium, tantalum, and even precious metals such as platinum and silver, thoughtful considerations of suitable applications have given birth to possibly an additional range of materials. Not unnaturally, all these metals are expensive, and fabrication problems are still something of a headache. Unfortunately, welding practices are somewhat limited for these alloys, and it may well be that soldering and brazing will be complementary to welding as a means of joining these metals. With its high strength-to-weight ratio and excellent corrosion resistance, titanium is especially useful as a fabrication material.

To overcome the expense of using some of these rarer metals, it may well be that they will find employment in the clad form. Some problems in the fabrication and welding of such metals are fairly obvious ; nevertheless, substantial progress has been made in producing commercial articles with respect to lined and other vessels.

In conclusion, it should be made quite clear that resistance to corrosion alone is not an adequate criterion for the selection of a material. Installation costs, plant shut-downs, and maintenance repairs should be borne in mind, and on some occasions resistance to corrosion must be sacrificed in order to obtain the minimum requirements for fabrication. For plant equipment required for duties in the chemical, atomic-energy, and petroleum industries, the quality of the end product is related to the operational control from the inception of the contract to the final vessel.

Plastic Ball and Roller Bearings

By J. E. MONTALBANO. (From *Machine Design*, Vol. 30, No. 16, August 7, 1958, pp. 96–99, 8 illustrations.)

REDUCTION in noise level during operation and excellent corrosion resistance of plastic bearing components are a few of the benefits directly attributable to inherent characteristics of plastic materials. A combination of steel balls and plastic races is used in household appliances, automobiles, business machines, and in other applications where quiet operation is desirable. Grease and dirt have adverse effects on steel balls, but do not impair the performance of plastic balls in steel races.

An example of an early application of plastic balls with high load-carrying capacity is the main azimuth bearing for the cupola of an American army tank. Evaluation of all-steel bearings during development of the cupola showed that grit, deposited in the bearing during normal field operation of the tank, caused an increase in friction torque, brinelling, and maintenance difficulties. Designing the azimuth bearing with plastic balls in steel races resulted in decreased weight and cost of the bearing assembly, and in trouble-free operation.

The specification of plastic bearings for applications such as that mentioned above reduces tolerance requirements considerably for both the balls and bearing races. Normally, steel balls require tolerances of approximately $\pm 0{\cdot}0001$ in., whereas plastic load-carrying balls require $\pm 0{\cdot}0005$ in., and idler, or separator, balls require only $\pm 0{\cdot}001$ in. The natural resiliency of plastic balls allows relaxed tolerances on steel races, which do not require additional surface hardening and do not need to be lapped and polished. However, some of the more highly loaded bearings having steel races and plastic bearing balls generally require heat treatment of the races.

Because plastic balls remain unaffected by dirt and grit and are impervious to corrosion, bearing sealing problems are much simplified. For rotational speeds under a 500-fpm pitch-line velocity, no lubrication is necessary. At higher rotational speeds, lubricants are used primarily as coolants.

BEARING MATERIALS

Application of plastic bearing components appear to be limited only by the number of available plastic materials and the inherent properties of each. Phenolic materials, cast into rods, cut, and centerless-ground to a tolerance of $\pm 0{\cdot}005$ in. on the diameter, proved adequate for the balls of the azimuth bearing already mentioned. After post-curing, a final grinding operation removed the hard surface and reduced the tolerance to $\pm 0{\cdot}0005$ in. Post-curing is often erratic, however, and removal of the hard surface by finish-grinding may cause the load-carrying ability of the balls to vary by 100 to 200%.

Cast-phenolic load-carrying balls, 0·406 in. in diameter, withstand a 200-lb load between flat plates before permanent set takes place. Ultimate failing values for these balls may range from 425 to 1000 lb, depending on post-curing operations. Adequate quality control will ensure an average failing load of at least 750 lb.

More than one hundred plastic materials were evaluated to determine their suitability for bearing components. The materials, tested with a variety of fillers, included urea, melamine, phenolic, and alkyd moulding compounds, and phenolic and epoxy casting compounds. A comparison of the eight most promising materials showed that unfilled compounds are superior to filled compounds for virtually all evaluation tests. Unfilled resin compounds show better resistance to water absorption and chemical attack than filled compounds. Fig. 1 shows typical deflection curves for melamine balls and Fig. 2 for plastic rollers of different diameters. These curves are based on test results and, in all cases, the ball or roller was loaded between flat hardened-steel plates.

Unfilled phenolic moulding compounds require an extremely long curing cycle (15 min for balls of $\frac{1}{2}$-in. diameter) and are not at present suitable for quantity production. Unfilled melamine compounds do not require such a long curing cycle, but present problems with entrapment of gases during moulding. The use of preforms and high-frequency preheating has, however, solved this problem to some extent. To achieve consistent uniformity in production quantities of unfilled melamine balls, rigid quality-control procedures must be followed. Curing cycles must be controlled to prevent shrinkage

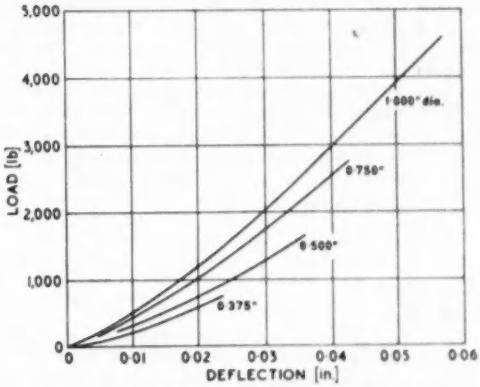

Fig. 1. Typical deflection curves for melamine balls of different diameters.

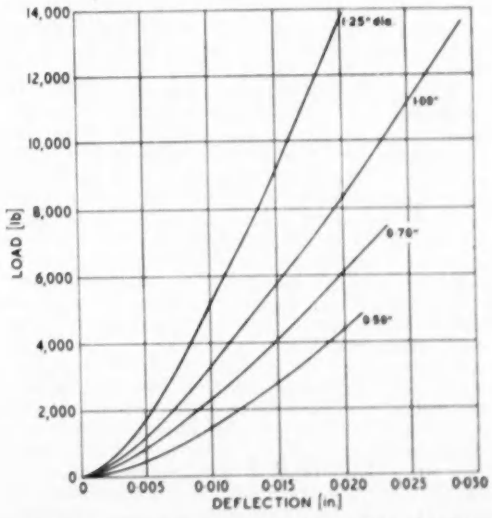

Fig. 2. Typical deflection curves for plastic rollers of different diameters.

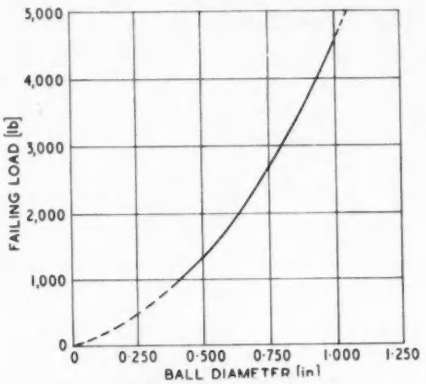

Fig. 3. Failing loads of melamine balls.

cracks during finish-grinding. The use of alpha-cellulose-filled melamine moulding compounds overcomes these difficulties with very little sacrifice in overall performance.

An increase of approximately 40 to 50% in the failing-load value of plastic bearing balls can be achieved by incorporating curved grooves in the bearing races. This increase, however, is not as great as that attained with steel balls in curved grooves. Relatively shallow grooves are recommended because of the increased deflection characteristic with plastic balls. Failing-load values for plastic bearing-balls are shown in Fig. 3.

Applications and Limitations

So far, plastic bearings have proved most useful in relatively low-speed applications, i.e., 15 rpm or 500-fpm pitch-line velocity. Recently, however, a 2-in. diameter plastic wheel bearing was developed which operates successfully at rotational speeds up to 1250 rpm. Lubrication is required only for heat dissipation. Also, excellent results were obtained with all-plastic bearings operating at 1250 rpm completely submerged in salt water.

In addition to their application in the main azimuth bearing for the cupola of a tank, 1-in. plastic balls, instead of steel balls, are used in the main-turret bearing assembly of another American light tank. This bearing, approximately 90 in. in diameter, supports the weight of the main-turret and machine-gun cupolas, absorbing all gun-recoil forces and accelerations imposed during high-speed travel over all types of terrain.

Additional design data are still required before the full potential of plastic bearings is realized. Relation of load-carrying capacity to rotational speed, life expectancy, and lubrication and heat-transfer characteristics must yet be determined. However, plastic bearings are being considered for applications in which corrosion, magnetic interference, and sparking cannot be tolerated.

Although plastic bearings exhibit excellent resistance to shock and impact loads and have proved satisfactory in particular applications, certain factors limit their acceptance on a large scale. All-plastic bearings are not mass-produced at the present time. Those that are available are larger than comparable steel bearings and require more space for given load conditions. Applications are limited to low speeds and to moderate temperatures of —65 to + 300°F. The maximum diameter of the laminated tubing from which bearing races are machined is limited at present to 36 in.

RUSSIA

A Piezo-Electric Method of Measuring Surface Roughness

By I. V. Dunin-Barkovskyi. (From *Vestnik Mashinostroyeniya*, Vol. 38, No. 7, July 1958, pp. 61-62, 4 illustrations.)

The instrument described in this article was developed at the Moscow Institute of Aviation Technology in connection with problems arising in the measurement of surface roughness on relatively soft light-alloy components, particularly inside deep holes of small diameter.

The advantages of the piezo-electric profilometer over other types are (1) the output is independent of traversing speed, so that the latter can be adjusted to suit the average pitch of surface irregularities, and (2) the contact pressure is low. This combination of low speed and low contact pressure means that the profilometer can be used on surfaces of much lower hardness than has hitherto been possible, without leaving a visible trace. Also, the small size of the stylus head used permits its insertion into holes as small as 37 mm in diameter, at depths up to 300 mm.

The piezo-electric element consists of two plates of barium metatitanate, 40 × 8 × 0·35 mm, cemented together. This material was chosen because it is not sensitive to variations in atmospheric temperature and humidity, although its output is less than, say, Rochelle salt. Fig. 1 shows the general arrangement of the stylus head. The stylus (1) consists of a sapphire cone, with an apex angle of 90 deg. and a tip radius of 10 microns, in a light-alloy mount rigidly fixed to the free end of the piezo-electric element (2). At each end of the stylus, and fixed to the main body, is a spring-loaded skid (3), which can be adjusted by means of a wedge (4). The wedge is adjusted in an axial direction by a micrometer screw (5), one scale division on the micrometer thimble (6) giving an adjustment of about 2 microns.

The stylus head is moved backwards and forwards over the test surface by means of a drive unit attached to an arm (7), the length of the path being 5 mm and the speed adjustable between 1·5 and 3 mm/sec. The skids travel over the peaks, providing a datum level, and the stylus follows the surface irregularities. Thus, the stylus oscillates vertically, deforming the piezo-electric element and producing an oscillating voltage at its terminals.

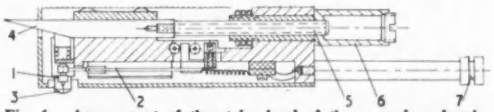

Fig. 1. Arrangement of the stylus head of the new piezo-electric profilometer.

These signals are fed to the input of a unit comprising amplifier and detector circuits and a dial indicator. The amplification factor is 4000 and is constant over a range of 10 to 1500 cps. The output can also be fed to a cathode-ray oscilloscope for visual observation of the profile. Normally, the dial-indicator scale is calibrated in proportion to the square of the output current, thus giving readings in terms of the r.m.s. value of surface irregularities.

A Combined Electrolytic Polisher and Microscope

By F. RÜMMELE*

ELECTROLYTIC polishing is being applied to an ever-increasing extent as a method of preparation in metal microscopy, and, within the framework of its applications, has a number of advantages compared with the mechanical polishing of metal specimens. Thus, a metal section can be polished considerably more rapidly and, as distinct from mechanical polishing techniques, the structure of the metal does not become smeared with a shattered surface layer. Structural etching can be carried out on electrolytically polished specimens in the same process as polishing in an incomparably shorter time, as the shattered surface layer need not be previously removed.

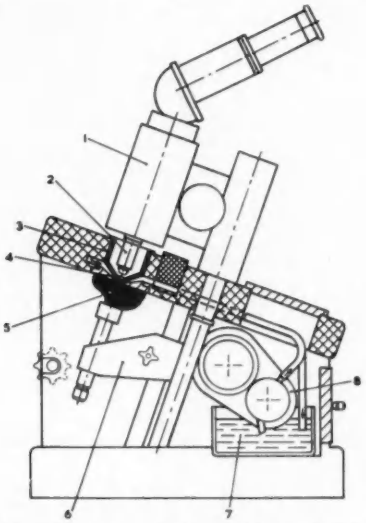

Fig. 1. **Schematic arrangement of the new Zeiss combined electrolytic polisher and microscope.**

(1) Direct-illumination microscope.
(2) Objective-lens system.
(3) Cathode.
(4) Window of cathode.
(5) Metal specimen.
(6) Specimen mounting.
(7) Container with electrolyte.
(8) Pump and motor.

Electrolytic polishing, which is based on the principle of dissolving the surface of the metal by the action of an electric current, therefore has its advantages. However, this dissolution must be effected in a certain manner and, although electrolytic polishing and etching effects can be produced within a wide range of electrical conditions, the quality of the polished or etched surface depends to a great extent on the applied terminal voltage and on current density, and the electrical conditions required for a particular quality of surface are in their turn determined by a number of factors, e.g., the type and condition of the specimen to be treated, the composition of the electrolyte, the resistances in the complete circuit, and the size, shape, and position of the electrodes. Also, the movement of the electrolyte exercises a decisive effect in this respect. At times, the influence of these various factors can only be comprehended with difficulty or not at all, so that the prevailing conditions can hardly be made reproducible. Even with simple instruments, it is thus possible only after a thorough study of electrolytic polishing and etching to obtain useful polished or etched metal specimens. Some instruments have therefore been developed with a view to keeping a number of the decisive factors constant by means of suitable control equipment, e.g., the size of the surface to be treated and of the cathode, as well as the shape and position of the electrodes, while certain measures have also been adopted with regard to the movement of the electrolyte. In this way, experienced laboratory assistants can usually prepare specimens which are suitable for routine investigation of the metal structure when conditions are defined regarding the electrical data for the instrument, the period of processing for the given specimen, the amount of preliminary grinding carried out, and the electrolyte.

Recently an instrument has been developed by Zeiss, combining an electrolytic polisher with a direct-illumination microscope in such a way that the surface of the specimen can continuously be observed and even photographed during the course of the treatment of the metal specimen. By means of this instrument, the specimen can be judged by the metallographer in a single process while polishing and etching are carried out, without having to subject the specimen to an intermediate treatment for the purpose of microscopic investigation. In the majority of series investigations in materials testing, this may easily result in a great saving in time, as it makes it possible, during the treatment of the specimen, to appreciate immediately the influence of the given electrical data, the processing period, the speed of flow of the electrolyte etc. on the surface condition. Thus, treatment of the specimen can be proceeded with and interrupted the moment the surface has attained the requisite finish.

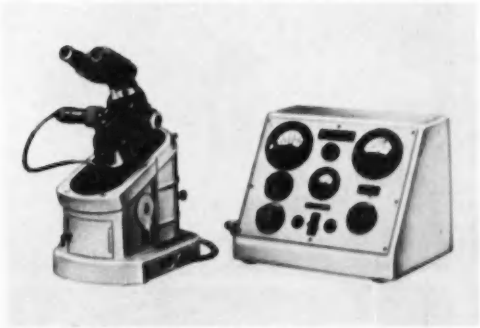

Fig. 2. **Combined electrolytic polisher and microscope and corresponding power pack.**

The design of the new electrolytic polishing instrument is shown schematically in Fig. 1. The metal specimen is held against a non-conducting diaphragm with a circular aperture of 6 mm diameter, and the specimen is observed from above through the electrolyte. The objective is protected by a cover, serving at the same time as a cathode, the lower opening of which is closed by a plane-parallel glass plate. The shape of the cathode, in conjunction with the correspondingly shaped diaphragm, ensures that a laminar flow of electrolyte is produced over the metal specimen, as is required for any good polishing

* Laboratory for Raw Materials and Surface Problems, Carl Zeiss, Jena.

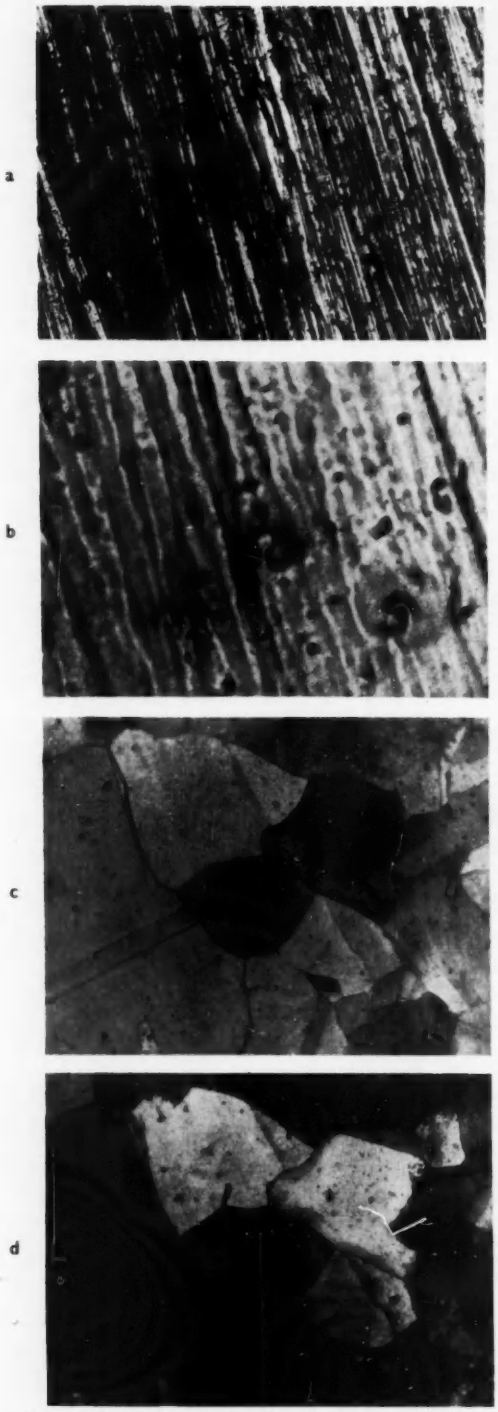

Fig. 3. Surface of a brass specimen during successive stages of electrolytic polishing and etching. ×200)

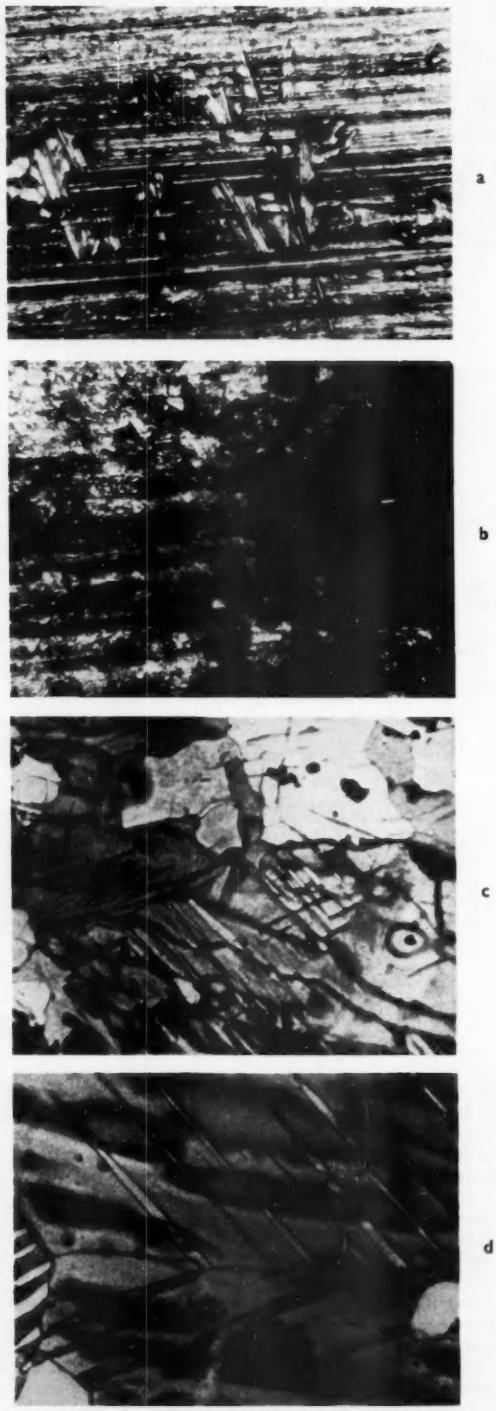

Fig. 4. Surface of a tin specimen during successive stages of electrolytic polishing and etching. (×200)

effect. This shaping also results in the treated specimen assuming under the influence of the existing electric field a condition which is as uniform as possible all over. Spare electrolyte is in a container at the back of the instrument, and, by means of a pump, circulates at an adjustable flow speed through the electrolytic cell. Observation of the metal surface can be carried out up to a magnification of × 200 in a bright field and also by polarized light. The microscope is a standard direct-illumination Zeiss instrument which can at any time be used with a stand for other microscopic azimuthal observations. Also, photomicrographs of the metal surface can be made during observation by connecting an attachment camera.

A separate mains-operated power pack supplies the instrument with current and permits the selection of direct current in the electrolytic cell continuously within the ranges 0 to 15 V and 0 to 60 V. The transformer, rectifier, and device for smoothing the rectified current of the instrument provide for currents up to 1 A, making it possible to work with anodic current densities up to about 4 A/cm². The electrical data at any given moment can be read on a voltmeter, set for the ranges 0 to 15 V and 0 to 60 V, and on an ammeter with ranges of 0 to 0·1 A, 0 to 0·5 A, and 0 to 1 A. The power pack also supplies the pump motor with the required direct current, and the voltage applied to the motor can be adjusted as required from 0 to 24 V and can be read on a voltmeter. The complete unit, comprising the power pack and the combined electrolytic polisher and microscope, is shown in Fig. 2.

A number of other devices are incorporated for safe and reliable use of the instrument. Thus, the mounting for the specimens is designed in such a way that any shape up to 100 mm in diameter and 30 mm in height can be fixed. With smaller diameters of, say, 20 mm, specimens of up to 100 mm in length can be attached. With regard to the shape of the specimen, all that is required is to have at least one circular plane area of approximately 8 mm diameter. The head of the mounting is provided with springs, which permit the removal of the specimen without loosening the set-screws, or, if another part of the surface of the specimen is to be treated, shifting it accordingly. By closing the space occupied by the specimen with a double-flap door, it is impossible to touch the live anode, as the circuit is interrupted when the door is opened. The cathode, which is accessible, is earthed. In addition, a switch at the foot of the instrument is provided for the immediate interruption of the circuit of the electrolytic cell. A push-button within easy reach of this switch makes it possible to turn on the current for a short time—a useful feature for obtaining a certain degree of etching at any set voltage at the terminals. Close to this switch is positioned the switch for the circuit of the pump motor. A tap in the cover plate of the instrument enables the draining speed of the electrolyte from the electrolytic cell to be adjusted. The cathode can be removed for cleaning by loosening a set-screw, and a stop prevents the window of the cathode from being damaged by the objective-lens system of the microscope. The door leading to the electrolyte container can be opened only when the pump has been tilted away from the electrolyte container by means of a lever. To obviate endangering the plastic pump by running dry, the electrical circuit for the pump motor cannot be closed unless the pump is tilted into the electrolyte. In all other respects, the instrument, with its largely corrosion-proof design, meets the rigorous demands placed on this type of apparatus.

An example of the work performed by the new instrument is illustrated in Fig. 3, which shows photomicrographs taken during the electrolytic polishing and etching of a brass specimen, which had originally been rough-ground with abrasive paper, the corresponding surface being shown in Fig. 3a. All photomicrographs are of the same spot on the specimen during treatment. After setting the speed of flow for the electrolyte, the terminal voltage is gradually increased from zero, resulting in a change in the surface of the specimen. The surface, with its grooves, is gradually and quite evenly coated with a brown layer of ever-increasing density. Finally, the layer becomes more transparent, breaking suddenly open and floating off in larger or smaller fragments. Underneath this layer a bright surface becomes visible (Fig. 3b), which, however, still shows some grooves. With a further voltage increase the smoothing process commences, until after a short time the surface is polished.

When increasing the voltage still further, gas bubbles form, causing the destruction of the polished surface. An increase in voltage up to this stage must be avoided, but, should it occur, the voltage is reduced until no more gas is generated and the polishing action becomes once again effective. If the voltage is reduced still more, grain boundaries become apparent (Fig. 3c). A further slight reduction in voltage results in a grain surface etching which soon leads to the entire surface being covered with the brown layer, but, by increasing the voltage, this layer is again removed, as described above. Underneath the floated-off coating the profile of the structure produced is clearly visible, this being removed only some time later by the effect of polishing (Fig. 3d).

To prevent an over-etched surface subsequent to polishing, the voltage is greatly reduced and then gradually increased until the exact degree of etching required is obtained. Also, with a higher voltage, the required degree of etching can be attained when, after switching off the electrolytic circuit, the push-button is depressed until the increasingly strong etching corresponds with the required surface condition.

A second example, illustrated in Fig. 4, shows the electrolytic polishing and etching of a tin specimen, the surface areas of which were transformed by a preceding grinding process, the initial state of the surface of the specimen being shown in Fig. 4a. In this case, after gradually increasing the terminal voltage, a dark top layer is also formed and covers the entire specimen. At somewhat higher voltages this top layer dissolves, revealing a bright surface still crossed by grinding grooves, (Fig. 4b). At a higher voltage these grooves are rounded off, and soon a polished metal surface is obtained. The structure of the metal surface layer becomes discernible almost immediately by reducing the voltage, and is the structure of a destroyed, re-crystallized surface layer, as can easily be recognized by increasing the voltage and penetrating further into the metal specimen by electrolytic polishing, meanwhile rendering the structure visible by reducing the voltage for a short time, until the result shown in Fig. 4c is obtained. The shattered, re-crystallized surface layer is removed to an increasing extent, until finally the coarse crystalline structure is revealed corresponding to the actual structure of the cast tin. From then on, further treatment no longer alters the structure of the metal, as shown in Fig. 4d.

These examples show how systematic work can be carried out with the new instrument, which makes it possible to attain an optimum surface by means of the electrolytes listed in the technical literature for the respective metals and, at the same time, to carry out microscopic observation in the course of the treatment.

A New Method of "Rivet Welding", using Coated Electrodes

By A. Ya. Brodskyi. (From *Svarechnoye Proizvodstvo*, No. 10, 1958, pp. 18–21, 8 illustrations.)

The welding of steel lattice structures, such as trusses, girders, and power-line pylons, which have hitherto normally been fabricated by manual welding, can be mechanized by means of the so-called "rivet-welding" process. Experience with this process shows, however, that, if the top plate is more than 3 mm in thickness, a hole must first be drilled in the plate, and such holes give rise to a characteristic defect, i.e., insufficient annular penetration. As a result, these holes must first be countersunk, and the additional preparation involved detracts from the efficiency of the process as a whole.

To overcome these disadvantages of the original rivet-welding process, which uses an uncoated electrode and a submerged-arc type of flux, a new and improved method, using a coated electrode, has been developed in Russia, by means of which, when the arc is struck, it commences to fuse a hole in the workpiece (Fig. 1a), thereby eliminating all drilling operations completely. An enclosed space is formed, bounded laterally by the coating of the electrode, above by the electrode tip, and below by the molten base of the hole. The stream of incandescent ionized gases, evolved as the electrode and its coating melt, builds up a pressure inside this space, and the molten metal from the workpiece and electrode flows around the rim of the coating and out over the surface of the workpiece. In this way, a seal is created around the electrode (Figs. 1b and 1c), ensuring the maintenance of pressure inside the hole. Consequently, an ever-increasing depth of metal is exposed to the direct fusing action of the arc. Because of this and the high heat concentration in the arc, thick material can be fused or pierced very rapidly and with comparatively low currents.

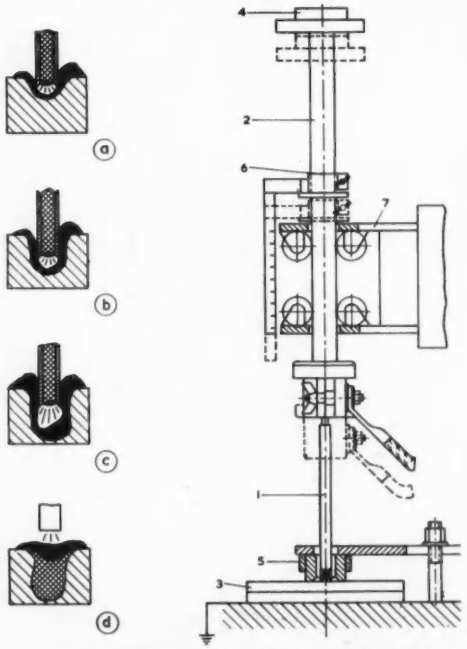

Fig. 1. (left) **Progressive stages of fusion in the new "rivet-welding" process.**

Fig. 2. (right) **Schematic arrangement of the automatic welding equipment.**

When the electrode has reached the required depth of penetration, the equipment is so designed that the arc length gradually increases, and the pressure of hot ionized gases in the hole therefore drops. The flow of molten metal gradually ceases, and a pool of molten metal forms under the electrode, so that the arc now burns between the electrode tip and the surface of the molten pool (Fig. 1d), imparting to the latter, heat which is transferred to the walls of the hole. The arc continues to burn until the entire hole formed by the fusing stage is refilled with metal.

Details of the new methods are shown schematically in Fig. 2, in which the coated electrode (1) is clamped to the end of a rod (2) and rests on the workpiece (3), contact pressure being increased by means of a weight (4) on top of the rod. Current is supplied via a conventional 1000-A welding transformer, means being included in the circuit to provide high-frequency arc ignition. The high frequency is switched off automatically by an electronic timer after 1·5 to 2 sec, and a choke is included in the circuit to prevent the winding insulation of the transformer from being perforated by high-frequency sparks.

On reaching the required depth of penetration, a control ring (6) contacts a bracket (7), impeding further downward motion of the electrode. As a result, the arc length gradually increases, as already mentioned. When the arc reaches the workpiece surface, the metal previously exuded is remelted, forming the rivet reinforcement in the copper ring mould (5), the height of which determines the extinction length of the arc and the amount of reinforcement deposited.

Thus, the process takes place in two stages, i.e., fusing or piercing and refilling, and these stages follow each other automatically, in accordance with preset conditions. The main parameters of the process are electrode type and size, current setting, electrode consumption (controlled by the position of ring (6)), axial load on the electrode, and the size of the copper ring mould (5).

Using these coated electrodes, it has been found possible to produce rivet welds which are free from cavities and porosity. It should be noted that acid-type coated electrodes have been found unsuitable, as they cause large shrinkage cavities in the rivets.

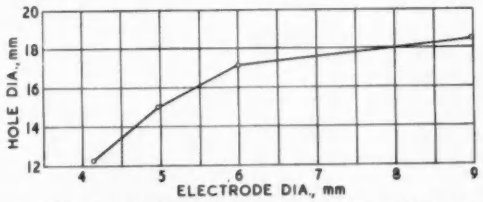

Fig. 3. **Diameter of the hole produced as a function of electrode diameter.**

With an increase in the diameter of the electrode, the diameter of the hole, which determines the strength of the rivet, also increases, rapidly at first and then more slowly, as shown in Fig. 3. With an increase in short-circuit current, the depth of penetration h increases (Fig. 4b), while the diameter b of the hole remains virtually constant (Fig. 4a). Thus, the form factor (b/h) decreases with increasing short-circuit current (Fig. 4c).

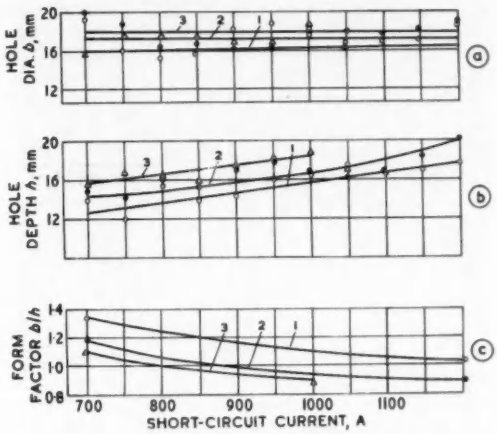

Fig. 4. Influence of short-circuit current on (a) hole diameter b, (b) hole depth h, and (c) form factor (b/h), for different electrode consumptions, using an electrode of 6 mm diameter and an axial load of about 6 kg.
(1) Electrode consumption = 20 mm.
(2) Electrode consumption = 25 mm.
(3) Electrode consumption = 30 mm.

The duration of the process varies with current and also depends on electrode consumption. With a small consumption (e.g., 20 mm), the time decreases slightly with increasing current, while, with a large consumption (e.g., 35 to 45 mm) an increase in current leads to a more marked reduction in the time taken.

The electrode consumption is related to the depth of penetration; the axial load also has a considerable effect at relatively low current settings, but less at higher currents. Thus, for example, with a current of 550 A, an electrode diameter of 6 mm, and a consumption of 45 mm, an increase in the axial load from 5·8 to 6·5 kg more than doubles the depth of penetration. At a current of 800 A, the same change in load (with an electrode consumption of 35 mm) causes a relatively small change in depth of penetration. Specific consumption, i.e., the weight consumed per unit of depth penetration, decreases more rapidly with increasing current setting than with increasing electrode consumption in terms of length. The current should therefore be set as high as possible with respect to the stability of the electrode and its coating.

To determine the strength of the rivets produced, an 8 × 8 × 80 mm. mild-steel angle and a 10 × 150 mm mild-steel plate were welded together by the new process, using an electrode of 5 mm diameter, an electrode consumption of 25 mm, a load of 6 kg, and a welding current of 850 A. The strength of each rivet produced was found to be about 4 tons. Similar welds were made between testpieces consisting of three plates of mild steel, each 12 mm in thickness, using electrodes of 6 mm diameter, an electrode consumption of 95 mm, and a welding current of 850 A. These welds were found to be much stronger than those on the unsymmetrical angle joints, the average breaking load being 12 tons, the welds in each case failing in shear. The new welding process is, however, capable of joining stacks of even more than three components.

At the moment, further investigations are in progress regarding the method itself and also in connection with the development of suitable equipment for industrial use.

U. S. A.

Erosion Damage to Solids by High-Speed Collision with Raindrops

By O. G. ENGEL. (From *Journal of Research of the National Bureau of Standards*, Vol. 61, No. 1, July 1958, pp. 47–52, 10 illustrations.)

THE problem of the erosion damage produced on objects flying at high speed into rain has become increasingly more serious as flight velocities have been increased, and considerable research has been carried out during the past ten years to find materials capable of resisting the stresses arising from high-speed collision with rain and to determine the mechanism of the erosion process.

In a previous publication*, the author has presented three factors which are important in analysing the damage produced by the collision of high-speed drops of water with methyl methacrylate. These factors are as follows :—

(1) The drop of water behaves like a hard sphere or pellet in that it produces a cup-shaped cavity in the plastic.
(2) Although materials do not usually fail under uniform compression, a local compression can produce tensile stresses which result in failure.
(3) In the case of projectiles which flow as a result of the collision, the solid plastic can be damaged by the stresses exerted by the flowing projectile against surface irregularities which are restrained by the underlying layers of material.

Further evidence of the behaviour of water under impact conditions was obtained in a study of the damage marks left by steel spheres, deforming lead pellets, and waterdrops as a result of high-speed collision with soft 1100 aluminium sheet. Fig. 1a shows an example of a damage mark made by a $\frac{7}{32}$-in. diameter steel sphere on $\frac{1}{4}$-in. 1100-H14 aluminium sheet. This particular damage mark was obtained at a relative impingement velocity of 228 fps. The diameter of this damage mark, as measured directly on the aluminium plate with a steel rule and magnifying glass, is about $\frac{1}{4}$ in., which is considerably less than the diameter of the steel sphere. Fig. 1b shows an example of a damage mark made by a 0·22-in. diameter deforming lead pellet on $\frac{1}{4}$-in. 1100-H14 aluminium sheet. This particular damage mark was obtained at a relative impingement velocity of 609 fps.

At a collision velocity of 880 fps, waterdrop damage marks observed in 1100-O aluminium resemble the mark left in 1100-H14 aluminium by impingement of a deforming lead pellet at very low velocity. When a waterdrop collides with 1100 aluminium at about 2000 fps, an impression is made which resembles that made by a low-velocity steel sphere more nearly than that made by a relatively low-velocity lead pellet (Fig. 1). These observations lead to the conclusion that, in the range of collision velocities up to about 1000 fps, a waterdrop behaves like a projectile that flows as a result of the collision but, at colli-

* O. G. ENGEL, *Jour. Research NBS*, Vol. 54, 1955, page 51.

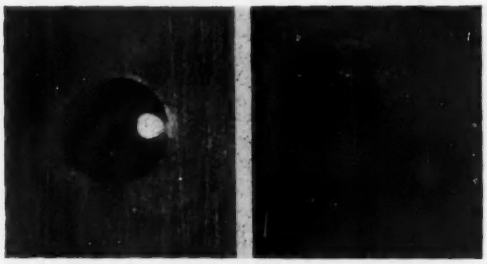

Fig. 1. Damage pits in 1100 aluminium formed by collisions with (a) a steel sphere at a velocity of 228 fps, and (b) a lead pellet at a velocity of 609 fps. (×4)

sion velocities of the order of 2000 fps, it behaves very much like a projectile that does not flow as a result of the collision.

Destructive Action of the Radial Flow of a Waterdrop

When a waterdrop collides with the planar surface of a solid, or when the planar surface of a solid runs into a stationary waterdrop, the resulting impact pressure reaches a high value in a very short time. This high pressure drives the liquid which is close to the solid surface radially outwards around a central stagnation point. The radially flowing liquid exerts a shear stress on the surface of the solid over which it is running. There is a shear stress between the separate layers of the flowing liquid itself, and it can be expected that a shear stress exists at the interface between the liquid and a solid surface over which it is moving. The shear stress τ between layers of liquid in laminar flow is given by the product of the viscosity μ and the velocity gradient through the moving sheet of liquid perpendicular to its direction of flow. In other words, $\tau = \mu(\partial v/\partial z)$, where v is the velocity of the moving sheet of liquid, and z is the direction through the thickness of the liquid sheet. The layer of liquid molecules in direct contact with the solid has zero velocity, but the velocity gradient is not zero, and the shear stress is applied to the solid.

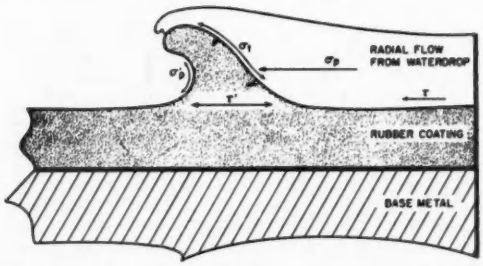

Fig. 2. Schematic diagram of the stresses in a surface protrusion of a rubber coating as the result of the radial flow of an inpinging waterdrop.

When a surface protrusion exists, the liquid from a drop flowing radially over it exerts forces against the protrusion acting in opposition to the cohesion of the protrusion to the underlying layers of material. The pressure σ_p in Fig. 2 is exerted against the protrusion by the flowing liquid. The pressure exerted by the liquid tends to move the protrusion along the planar surface of the solid and results in a shear stress τ' at the base of the protrusion. The flow of the liquid results in the shear stress τ discussed above. The pressure exerted by the liquid also results in a turning moment which tends to bend the protrusion over. The turning moment is the integrated cross product of the compressive force exerted by the liquid and the elevation of the protrusion above the planar surface of the solid at the point where the force is applied. As the protrusion bends, a tensile stress σ_t appears on the side of the protrusion against which the compressive force is applied, and a compressive stress σ_p' appears on the opposite side of the protrusion. If the force exerted by the rapidly running liquid is sufficiently great, or if the protrusion has a sufficient elevation above the planar surface, failure may occur. Whether the protrusion is simply bent over, whether it is broken off, or whether part of the solid material below the surface is torn out with it depends on the strength of the material and on where failure occurs first. Likely points of failure are marked with notches in Fig. 2.

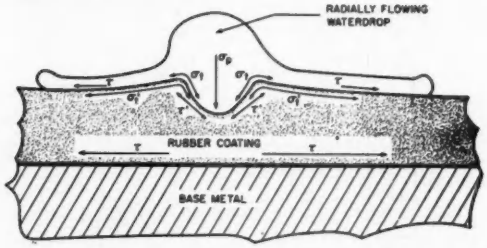

Fig. 3. Schematic diagram of stresses in a rubber-like coating as a result of the collision and flow of a waterdrop.

If a waterdrop impinges against the planar surface of a rubber-like material, the effect of the compressive stress σ_p in Fig. 3, which is the direct result of the collision, is to compress the solid material at the point of impingement. The local compression results in a dimple or cup-shaped cavity. Tensile stresses σ_t appear in the sides of the dimple and especially in the knee in the solid material at the rim of the dimple. If these tensile stresses are sufficiently great, tears may form in the surface layers of the solid material. The material which formerly occupied the volume that now forms the hollow of the dimple is displaced and is moved radially outwards and upwards around the dimple, resulting in a shear stress τ'. The radial flow of the liquid of the drop imposes a radial tensile stress σ_t' and a shear stress τ. In the case of very thin rubbery coatings, it is possible that a portion of the shear stress τ may be transmitted through the coating to the primer bonds, which hold the coating to the base metal, and that it may cause failure of the primer-to-rubber or of the primer-to-metal bond. However, the removal of a circle of rubber coating around the central

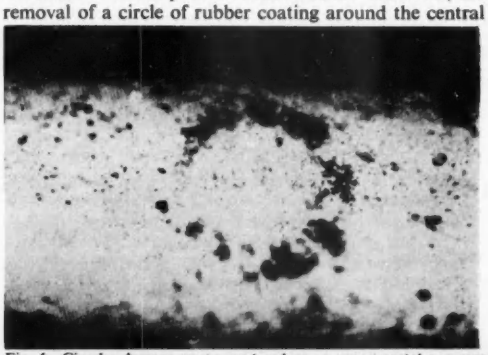

Fig. 4. Circular damage marks produced on an experimental neoprene coating in collision with waterdrops at a velocity of 880 fps. (×35)

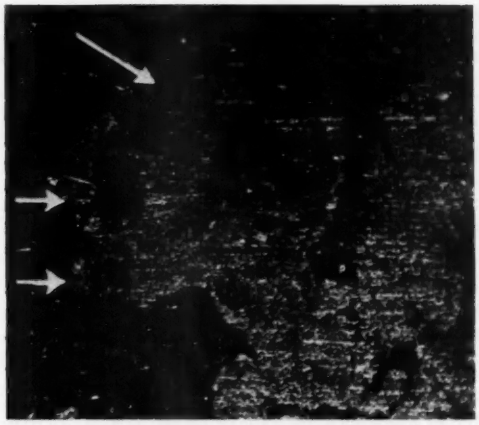

Fig. 5. Circular damage marks produced on neoprene by collision with waterdrops at 2250 fps.

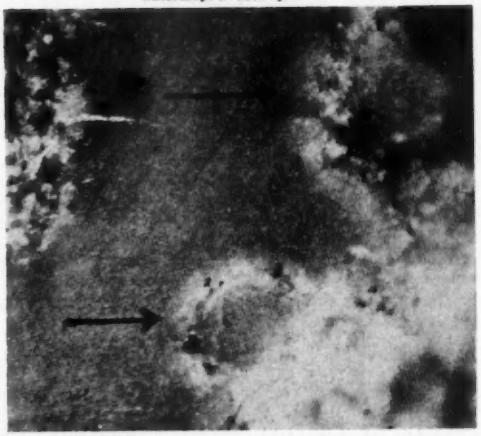

Fig. 7. Circular damage marks produced on Teflon by collision with waterdrops at 2250 fps.

point of the collision (stagnation point of the flow), as occurred in the case of a neoprene coating (Fig. 5), is not necessarily the result of transmission of this shear stress through the coating. It is possible that a deep circular cut may form as a result of the tensile stress σ_t (Fig. 3) in the material at the rim of the dimple or cup-shaped cavity. If this cut extends through the coating, the radially flowing liquid may lift the coating with a wedge action and peel it off.

The effect of the forces coming into play when the liquid of an impinging drop flows radially can be seen in the marks left when waterdrops fall into fine moist sand. To obtain a picture of such traces, slightly moistened sand of very fine mesh was gently pressed into a large Petri dish, and its surface was then levelled and lightly covered with carbon-black to as uniform a degree as possible. Waterdrops were allowed to fall from a flat-nosed pipette through a distance of approximately 40 ft to the surface of the carbon-covered sand. The waterdrop traces obtained showed clearly the existence of the stagnation point at the centre of the flow, where the radial flow velocity was zero; at this point the carbon was not washed from the surface of the sand. A circular trench about the stagnation point is the result of the forces that

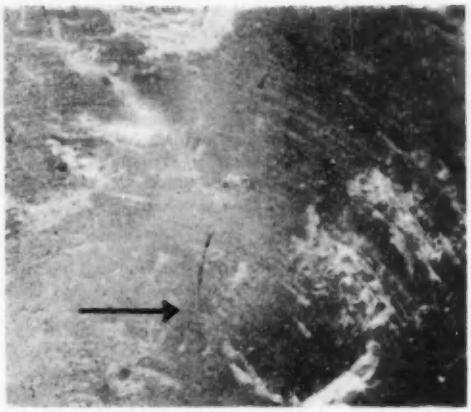

Fig. 6. Circular damage mark produced on methyl methacrylate by collision with waterdrops at 2250 fps.

act as a consequence of the radial flow of the liquid. The relative collision velocity was about 25 fps.

Traces similar to those formed when waterdrops were allowed to fall into the Petri dish of carbon-covered sand were also found on a neoprene-coated specimen that was rotated on the Cornell Aeronautical Laboratory rain-erosion test apparatus at a velocity of 880 fps through an artificial rain of 1 inch per hour for 1·5 min (Fig. 4). The average coating thickness was 8 to 10 mils. Because the surface was not completely covered with such damage marks, it seems likely that traces of this kind are not produced by the first waterdrop collision with the unfatigued neoprene coating. They are probably formed during a single collision, but only after the coating has suffered deterioration of some kind (possibly permanent set) as a result of numerous radial stretch-and-recover cycles imposed by the radial flow of waterdrops which collided earlier, but which were not themselves able to produce the observable damage.

Tests were conducted on a number of polymeric materials, including neoprene, methyl methacrylate, and Teflon, to determine the damage occasioned by collision of the material with waterdrops at a velocity of 2250 fps. The damage marks produced are illustrated in Figs. 5, 6, and 7, the arrows indicating the circular waterdrop traces in each case. In the case of neoprene (Fig. 5), which in this test was a standard coating, the undamaged centres marking the stagnation point of the radial flow are very clear in the two traces at the left of the illustration.

These illustrations show that the forces exerted by the radial flow of a waterdrop as a result of collision with the planar surface of a solid at a velocity of 2250 fps are a very effective cause of damage.

Response of Structural Materials to High-Speed Waterdrop Impingement

The damaging properties of an impinging liquid drop, as considered in the preceding sections, are similar for drops of all liquids but vary in intensity, depending on the density of the liquid, on the relative collision velocity, and on the extent to which the solid material yields under the blow. If the characteristic properties of all structural materials were the same, the appearance of damage marks produced by the impingement of drops of a given liquid against all of them at some arbitrary velocity would also be the same ; there would be only

one type of damage and only one mechanism by which the damage is produced. Because the characteristic properties of structural materials are different, there are as many different damage processes as there are broad groups of material properties. A specific question posed at the time that the research programme on the mechanism of high-speed rain erosion was initiated was whether a soft rubbery material or a hard rigid material should be sought as a solution to the rain-erosion problem. These two extreme cases are considered below.

Rubber-like Yield :—

A material which behaves like rubber under the blow resulting from collision with a liquid drop has the advantage of being a pressure reducer for the blow. When the impact pressure is reduced, the velocity of the radial flow of the liquid of the drop, which is driven by the impact pressure, is also reduced. Because the radial flow velocity is reduced, the shear stress that it exerts, which decreases as the radial flow velocity decreases, is likewise reduced. The material is, however, depressed at the point where the liquid drop strikes, and radial tensile stresses appear in the sides of the cup-shaped depression, and around and especially over its rim as it forms. The surface layers of the material around the restricted area of contact between the drop and the surface of the solid are also stretched as a result of the rapid flow of liquid from the drop. A material of this kind need only have strength properties sufficient to withstand the mitigated stresses in order to remain undamaged on colliding with a liquid drop.

An increase in the indentation hardness of a rubber is commonly accompanied by a decrease in its elongation under a given stress and therefore by a decrease in its ability to mitigate the stresses imposed on it by high-speed collisions with a waterdrop. The indentation hardness associated with maximum resistance against waterdrop-impingement damage at an arbitrary collision velocity is that hardness above which the gain in strength often accompanying further hardening is unable to offset the loss in ability to mitigate the stresses imposed by collision with a waterdrop at the velocity in question. In terms of the rupture energy per unit volume, the optimum indentation hardness is that hardness above which the area under the stress-strain curve begins to decrease.

Resistance of Hard Materials :—

All materials yield to some extent under a collision blow. However, materials that do not display high elongation under a given stress as a result of collision with a liquid drop do not mitigate to a notable degree the stresses exerted by the colliding drop. To be erosion-resistant, materials of this class must be able to withstand the unmitigated stresses. Whether or not they can withstand such stresses depends on whether they can absorb the energy of the collision before their yield or fracture strength is exceeded. If the relative collision velocity between the solid material and the liquid drop is increased without limit, all the known hard materials will be found to fail at the point where their yield or fracture strength is exceeded ; they will either yield with plastic flow or they will shatter.

Methyl methacrylate is a practical, rigid-material solution to the rain-erosion problem for flight velocities up to 300 mph. When specimens of methyl methacrylate are rotated through a 1-iph simulated rain at a velocity of 300 mph, initial pitting of the plastic occurs after 45 min. If, however, the velocity is increased to 400 mph, initial pitting occurs after 2 min. Test results show that polystyrene and the glass-cloth-reinforced polyester resins are less resistant to rain erosion than methyl methacrylate. The combined properties of rigidity and low strength eliminate these polymers as practical rain-erosion resistant materials at ordinary flight velocities.

Metals undergo permanent plastic flow when their yield strength is exceeded. In the case of 1100-O aluminium, the depression in the surface caused by a single collision with a waterdrop at a velocity of 600 mph is barely perceptible. The pummelling action of repeated collisions produces, by plastic flow, a general unevenness of the surface. This unevenness appears to play a role in enhancing a delayed, drastic failure of the material. Moderately thin specimen plates of the soft and medium-hard metals undergo considerable plastic flow during a single collision with a waterdrop at velocities in the range of about 1000 to 2000 fps.

The hard metals are known to afford a practical solution to the high-speed rain-erosion problem at moderately low impingement velocities. Incipient failure shows up only after hours of waterdrop impingement in the erosion test at a velocity of 500 mph in a 1-iph rain density. The failure of the hard metals in this range of impingement velocity cannot be explained in terms of the impact pressure produced by collision with a waterdrop. It appears to involve pressure-raiser defects, such as microscopic pits and pores on the surface of the specimen, or weak spots in the material at or close to the surface, or both.

Of the materials tested for resistance against collision with waterdrops at high relative impingement velocities, the ceramics have been found to be among the most resistant. However, if the impingement velocity is increased without limit, these materials also shatter at the point where their fracture strength is exceeded. A practical tensile strength of 30,000 psi can be expected from polycrystalline alumina.

REQUIREMENTS FOR RAIN-EROSION RESISTANCE

The question posed several years ago as to whether the solution to the high-speed rain-erosion problem should be sought among the soft rubbery materials or among the hard rigid materials can be answered in the following way. The material may be hard and rigid, or it may be soft and rubbery, and still have a high degree of rain-erosion resistance. If it is hard and rigid, it must have strength properties that will enable it to withstand, without fracture and without plastic flow, the maximum unmitigated stresses imposed by collision with a waterdrop in the velocity range for which the material is being tested. If it is soft and rubbery, it need only have strength properties sufficient to withstand the mitigated stresses imposed by collision with the waterdrop. The velocity ceiling for the rubbery materials is the point at which they are no longer able to withstand the mitigated stresses.

These remarks apply to the ability of a material to withstand a single waterdrop blow. Under actual flight conditions, successive blows on the same spot have a certain probability of being very closely spaced in time. Therefore, under flight conditions, a rain-erosion-resistant rubbery material must not only have strength properties adequate to withstand the mitigated stresses but must also recover fast enough to be able to mitigate the stresses of an additional blow to the extent that they do not exceed its strength properties. To be a practical rain-erosion-resistant material the rubber must, furthermore, not lose its ability to mitigate the stresses through deterioration of any kind during its expected service life.

The Magnetic Properties of Thin Ferromagnetic Layers

By H. MAYER. (From *Metalloberfläche*, Vol. 12, No. 9, September 1958, pp. 257-262, 12 illustrations.)

The ferromagnetic properties of thin layers show characteristic changes, increasing in intensity as the layer thickness decreases below a critical limit. Under certain conditions, the magnetism may vanish completely if the layer is thin enough. The phenomena are important for the theory of ferromagnetism and for technical applications of thin magnetic layers, e.g., in electronic computers.

THE magnetism of three-dimensional polycrystalline ferromagnetic solids is explained by the assumption that within small domains the spin of certain electrons in almost all atoms is orientated by interaction so as to have parallel moments. This leads to a resultant magnetizing vector for each domain and, in the de-magnetized state, this vector would be zero, because the component vectors would have random orientation. These domains can be observed experimentally if a colloidal suspension of fine ferromagnetic particles is placed on the surface of such a ferromagnetic body. Because of the strong stray fields at the boundaries between domains, the powder particles are deposited preferentially at these boundaries. Observation under the electron microscope has shown that transition from the spin orientation of one domain to that of a neighbouring domain occurs over a distance of 10^{-6} to 10^{-5} cm, so that the domains are separated by " walls " of a certain thickness, e.g., 10^{-5} cm in the case of cobalt.

A second, more advantageous method of observation uses the magneto-optic Kerr effect. If polarized light is reflected from a mirror surface of a ferromagnetic solid, its plane of polarization is rotated according to the position of the magnetizing vector. The difference in rotation on reflection from different domains can be changed into a difference in light intensity by the usual optical polarization methods and can thus be visually or photographically observed, or can be measured by a photocell. In thin layers, changes in the domains during magnetic changes can be followed cinematographically, and both surfaces of a layer can be observed under equal conditions or even simultaneously. In very thin layers, the rotation of the plane of polarization can also be observed by transmitted plane-polarized light.

The position of the magnetizing vectors in the domains must satisfy the condition that the density of the free magnetic energy E has a minimum value. This energy is determined by four factors, i.e., (1) the ferromagnetic single crystal is anisotropic and has a preferential direction of minimum magnetic energy (crystal-energy factor E_c) which would be the direction of the vector if no other condition intervened ; (2) owing to the magnetostrictive effect, any tension or compression acting on the crystal gives a preferential direction to the spontaneous magnetization (stress-energy factor E_s) ; (3) the magnetic energy of the domain in its own magnetic field is determined by the anisotropic shape of the domain (form-energy factor E_f) ; and (4) the walls, where the directions of most spin vectors deviate from those of the adjoining domains influence the total energy (wall-energy factor E_w). The condition of minimum energy density, which determines the structure of the domains of a spontaneously magnetized ferromagnetic solid, is thus

$$E = E_c + E_s + E_f + E_w$$

If an increasing external magnetic field is applied, the domain vectors of spontaneous magnetization obeying the above minimum condition are increasingly forced into the direction of the applied field, either by rotation of the vectors, without any change in the volume of the single domains, or by a growth of those domains having their vectors already more or less in the direction of the applied field. The rotation process requires a much higher energy than the growth process, but its characteristic time constant is from 10 to 100 times smaller. Modern experimental techniques permit observation of domain growth by indicating the displacement of the walls.

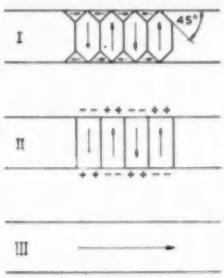

Fig. 1. **The three possible arrangements of domains in thin mono-crystalline stress-free magnetic layers.**

Theoretical discussions are based on a simplified unicrystalline coherent ferromagnetic layer. When the layer thickness approaches that of the walls between domains, i.e., 10^{-5} cm (1000 Å), it is obvious that any walls remaining in the layer must be more or less normal to the plane of the layer. The remaining three possible structures of domains in the simplified unicrystalline stress-free layer with only normal walls are shown in Fig. 1, and their estimated free magnetic energies in

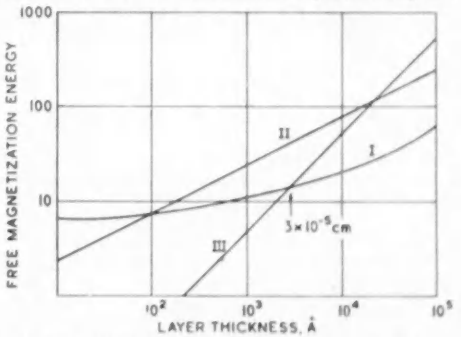

Fig. 2. **Free magnetization energy per unit of layer area as a function of layer thickness for the three arrangements shown in Fig. 1.**

Fig. 2. Above 3000 Å thickness, structure I has the lowest energy, while at smaller thicknesses structure III is more favourable, where the whole layer forms a single domain with a magnetizing vector parallel to its surface and thus presents a completely magnetized permanent magnet with remarkable properties. During transition from structure I or II to III, a subdivision by a few walls normal to the plane of the layer may still exist, but in all the domains and the walls the vectors can be expected to be parallel to the layer plane. If all three dimensions of a particle become very small, no walls can be expected to persist, so that magnetic changes are possible only by

rotation. Hence, thin layers, which often consist of such geometrically very anisotropic small particles, will require a very high coercive force for magnetic reversal.

Investigations have shown that, even under practical conditions, in thin but polycrystalline and stressed ferromagnetic Ni-Fe layers these conditions are largely fulfilled. The walls are, in fact, normal to the layer surfaces, the walls of the lower surface appearing as mirror images of those of the upper face. Moreover, the magnetizing vectors of the domains are in the plane of the layer and " anti-parallel " in adjacent domains, i.e., the walls are so-called 180-deg. walls. On the other hand, an evaporated Mn-Bi layer of 1000 Å thickness has produced the structure II in Fig. 1, with vectors perpendicular to the layer surface, probably because of the particular hexagonal lattice arrangement. Observations of the stages in the reversal of magnetization due to a field applied parallel to the preferential vector direction in the plane of a cobalt layer have shown that dark reversed domains initiate at points of disturbances at the edges or at disturbing inclusions inside the layer, and expand in a dagger-like manner until finally the layer again forms almost a single domain with reversed magnetization.

These results with polycrystalline layers have been confirmed by experiments with single-crystal layers produced in thicknesses up to 1500 Å by evaporation from electrically heated iron foil.

In a magnetizing or reversing field parallel to the preferential vector direction, a single domain must have a rectangular hysteresis loop, because an applied decreasing field cannot change the preferential position of a parallel vector ; consequently, neither can it change the magnetic saturation value determined by this vector. Only after field reversal and attainment of a value corresponding to the coercive force can the magnetizing vector have an opposite direction. This condition is obtained in practice on Ni-Fe and Ni single-crystal layers.

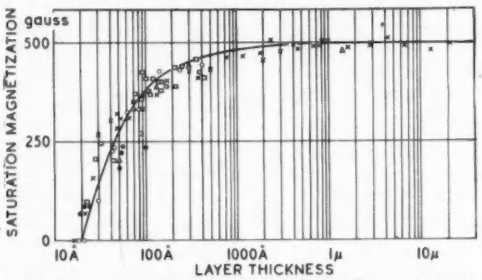

Fig. 3. Summary of experimental results by various investigators of the relative saturation magnetization of thin nickel layers as a function of layer thickness.

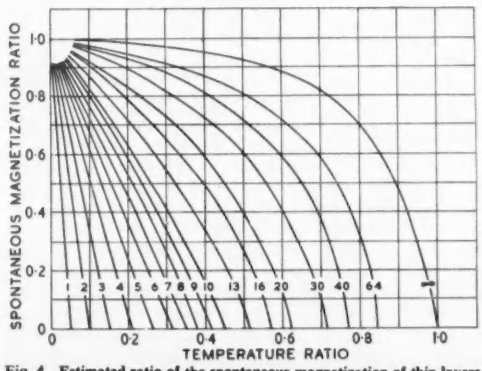

Fig. 4. Estimated ratio of the spontaneous magnetization of thin layers to that of the thick material as a function of the ratio of temperature to Curie point.

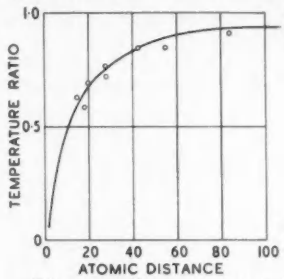

Fig. 5. Ratio of temperature to Curie point of thin nickel layers as a function of layer thickness.

The reversal may proceed by domain growth, as shown directly by the Kerr method, but also by vector rotation, as shown by the appearance of a strong magnetizing component at right angles to the preferential direction in the layer plane. Since rotation takes less time than domain growth, resonance and pulse methods have been applied to clarify the problem. The results appear to indicate rotation, but are still inconclusive. A solution could be important in the case of electronic computers where speed is essential.

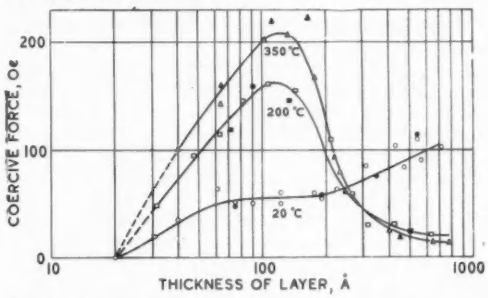

Fig. 6. The coercive force of iron layers evaporated on glass (open test-points) and on NaCl carriers (solid test-points) as a function of layer thickness for various carrier temperatures.

Since interaction between atoms produces parallel spin for spontaneous magnetization, a layer thickness too small for interaction between a sufficient number of atoms must reduce the magnetization to zero, i.e., the ferromagnetism must disappear or change to the paramagnetism of the single atoms. Experimental results on nickel and iron layers confirm theoretical expectations, as shown, for instance, in Fig. 3, where relative saturation magnetization, referred to the mass of the body, first decreases slowly for thicknesses below 250 Å (about 100 atomic distances), then drops more rapidly below 100 Å (40 atomic distances), and finally reaches zero for layers of about 4 to 5 atomic distances.

Theoretically, ferromagnetism can be interpreted in terms of wave mechanics as a consequence of interaction between atoms, and, if these considerations are applied to layers, the diagram shown in Fig. 4 can be obtained, in which each curve gives for various numbers of atomic layers the ratio of the spontaneous magnetization to that of the mass of the body, as a function of the ratio of the temperature to the Curie point of the material. It can be seen that, for a thickness below about 70 atomic distances, spontaneous magnetization decreases rapidly with layer thickness for a given value of temperature. On the other hand, this theory indicates that even biatomic or

monatomic layers can be ferromagnetic at a sufficiently low temperature ; however, no experimental evidence is as yet available.

Fig. 4 also shows that the Curie point of a layer depends on its thickness. For layers a few atoms thick it may be at room temperature or even below (Fig. 5).

If the layer is so thin that walls can no longer be formed and reversal must be caused by vector rotation, coercive force must rise, especially if the geometrical anisotropy is pronounced, because the vector is forced to turn from its preferred direction through directions of more difficult magnetization into the direction of the reversed field. Experimental evidence is shown in Fig. 6 for iron layers, but is also available for nickel and cobalt layers. If the temperature of the carrier for the evaporated layer is sufficiently high for the order and crystallization processes required for domain growth in sufficiently thick layers to take place, then coercive force rises when the layer thickness drops below 500 Å. On the other hand, for very thin layers below about 100 Å, coercive force decreases again as a result of the decreasing extent of spontaneous magnetization, as, for instance, in Fig. 3.

GERMANY

Scale-Free Heating of Metals in Lithium Atmospheres

By F. NEUBERGER, L. RÖTZ, and L. MÖCKEL. (From *Monthly Technical Review*, Vol. 2, No. 6, June 1958, pp. 150-154, 14 illustrations.)

THE hot forming of metallic materials is usually accompanied by scale formation, the effects of which are well-known. Processes have been developed for the purpose of heating metals without appreciable scale formation. These processes are, however, practically never used in normal forging shops, chiefly owing to economical considerations and to the rather complicated construction of the required plant.

After World War II attention was directed to a process which to all appearances was able to answer most practical requirements. This process operates with lithium vapours in the furnace atmospheres and is claimed to prevent the formation of scale, as well as the decarburization of the external layers of workpieces within and outside the furnaces by the formation of a protective film. As, however, basic information was not available on the operating conditions of these furnaces, on the limitations of the process, and on the construction of the main aggregate and the auxiliary equipment for operation of furnaces with lithium atmospheres, it was therefore considered desirable to attempt to clear up some of the problems associated with this process.

For this purpose, preliminary experiments were carried out, using an industrial furnace with an upper heating chamber of 160 × 280 × 100 mm and a combustion-chamber of 160 × 220 × 70 mm, the maximum temperature obtainable in the heating chamber being 1000°C and in the combustion chamber 1200°C. The furnace was heated with gas containing 41·8% hydrogen, 9·6% carbon monoxide, 20·6% methane, 20·2% nitrogen, 4·8% carbon dioxide, 0·6% oxygen, and 2·4% olefines, acetylene, and benzene. Measurement of gas and air volumes passed through the furnace was effected by flow-meters, and of gas and air pressures by U-tube manometers. Temperature measurements were carried out with an optical pyrometer.

The original intention was to introduce vaporized lithium or lithium compounds mixed in a carrier gas, but preliminary experiments in this connection indicated that this method was technically impossible by simple means. An alternative method, which proved quite satisfactory, was devised and involved the introduction of lithium compounds into the furnace through the gas pipe, using a piston, as shown in Fig. 1.

Cylindrical test specimens of steel, 30 mm in diameter and 40 mm in length, were heat-treated in the lower chamber of the furnace for different periods at a furnace temperature of 1100°C, and were allowed to cool in air. Tests were carried out on specimens heated with and without the presence of lithium, and in atmospheres containing varying amounts of air, these air factors λ being classified as " poor ", i.e., deficient in air (λ = 0·8 to 0·9), " average " (λ = 1·0), and " rich " (λ = 1·2). The heat-treating periods were 15, 20, 25, and 30 min, and lithium was introduced into the furnace in the form of lithium carbonate. The degree of effectiveness of lithium atmospheres was determined by comparing specimens heated under identical conditions in normal furnace atmospheres with and without lithium. The extent of scale formation observed on the comparison specimens is shown in Fig. 2 for different air factors λ.

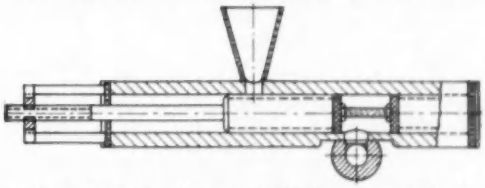

Fig. 1. **Method of introducing powdered lithium compounds into the furnace through the gas pipe.**

The presence of lithium in the furnace atmosphere was indicated by flames of a characteristic red colour, facilitating considerably the correct control of lithium feed, which should be introduced into the combustion chamber at its hottest point, i.e., through the burner or in its immediate neighbourhood.

The specimens were found to be covered with a very thin, dark, shining protective layer which protected them against scale formation, even during the cooling-off period in air. The dimensions of the heat-treated specimens must not drop below certain limiting values, and a certain time-temperature difference must prevail between the surface of the specimens and the temperature of the furnace atmosphere. These conditions are required for the deposition of the lithium vapour at furnace temperature on the relatively cool workpieces before scale formation commences. The minimum dimensions required depend on local operating conditions.

The degree of effectiveness of a lithium atmosphere depends on the adjustment of combustion conditions. Reducing combustion is required, although the fundamental reactions have not been investigated. Corresponding statements in technical literature disagree considerably, but the present experiments indicate that the

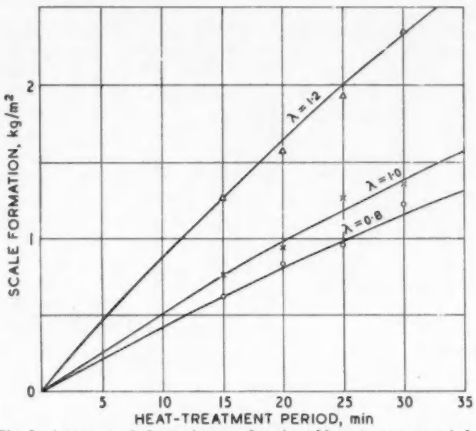

Fig. 2. **Average scale formation as a function of heat-treatment periods for various air factors λ.**

limits of effectiveness lie at about 10% air deficiency (at furnace temperatures of 1100°C), the heat-treating periods exerting no influence on the quality of the specimen surfaces. There was no scale formation, provided that the atmosphere contained sufficiently large quantities of lithium. Scale formation was completely avoided in the presence of 10 grams of lithium carbonate per cubic metre of gas, the amount depending on the operating conditions involved.

Experiments under Practical Forging Conditions

For the purpose of experiments carried out under practical forging conditions, a small gas-heated furnace of simple design was used, the gas in this case containing 52·3% hydrogen, 11·4% carbon monoxide, 22·5% methane, 6·9% nitrogen, 4·1% carbon dioxide, 0·5% oxygen, and 2·3% olefines, acetylene, and benzene. The combustion process was adjusted in accordance with the appearance of the flames, and furnace temperatures were controlled by means of a pyrometer.

It was found that the method of introducing pulverized lithium carbonate shown in Fig. 1 was quite unsuitable for use under these practical operating conditions, as the gas pressure in this furnace was 160 mm w.g., as compared with 80 mm w.g. in the furnace used in the preliminary experiments. As a result, an arrangement was devised, working on the reverse principle, i.e., the lithium carbonate powder was sucked, instead of being blown, into the gas line. This arrangement basically comprises a tube introduced into the furnace, a storage funnel, and a shaker for preventing clogging of the funnel exit, the cross-section of which can be adjusted.

In these tests, bicycle cranks and clutch levers of two different steels were forged, the blanks of the cranks having previously been subjected to preliminary upsetting, and the blanks of the clutch levers to preforging and cleaning of fins.

Before commencing with annealing operations, it was considered necessary to investigate the influence of furnace and blank temperatures and the surface temperatures of the blanks leaving the furnace. Experiments carried out at furnace temperatures between 1000° and 1300°C indicated that, under the test conditions involved, metallic bright surfaces were not subject to scale formation, as long as the furnace and blank temperatures remained below 1200°C, while above these temperatures the characteristic flame colours gradually disappeared. The quality of the surface of the forgings dropped in the same manner. It is believed that this is due to the reciprocal effects of individual constituents of the furnace atmospheres, i.e., the ratio of CO to CO_2 and of H_2 to H_2O, such as must also be considered in the application of the customary protective gas atmospheres, e.g., incompletely burned coke-oven gas. It was found impossible to determine exactly the influences which were directly responsible for this phenomenon, owing to the lack of suitable measuring instruments.

Forgings free from scale were obtained whenever the furnace and blank temperatures did not exceed 1200°C. Parts heated and forged in this way exhibited surface conditions unknown in workpieces heated in conventional forging furnaces.

The surface condition of heated blanks cannot be better than that in which they have been charged into the furnace. A metallic bright surface therefore represents the ideal state. In the case of bicycle cranks produced from metallic bright blanks, scale formation was found to take place only to a slight degree at the fins, where, on account of the long distance of flow, the protective layer was torn away. Pickled and sand-scoured blanks can be used, although the forged parts exhibit the sand layer beside the protective layer. This initial condition is generally without importance. In normal experimental operations, all blanks are usually sand-scoured in order to avoid the formation of scale, and its application in the present investigations appeared to be necessary. Scouring of the blanks with steel shot prior to heat treatment is insufficient, in view of the fact that part of the scale layer remaining from the first operating stage is left beneath the protective layer.

Following preparatory treatment, about 6000 clutch levers were forged. After a few hours of uninterrupted operation, the amount of lithium carbonate declined considerably. It appears that the lining of the furnace absorbs a considerable percentage of the lithium during the first part of the treatment, and this is then gradually returned into the furnace atmosphere. It was found, even a few days after the end of the tests, that some workpieces heated in the same furnace were partly covered with lithium. An amount of 1045 gm of lithium carbonate was required for the 6000 forgings (340 gm per blank) subjected to the investigation.

The heat treatment of the blanks in furnace atmospheres containing lithium vapour exerts a favourable influence on the total output capacities of the forging tools. The forging die was made of a Ni-Cr-Mo-V steel with a strength of 140 to 145 kg/mm². The average maximum capacity of a forging-die plate was normally 2500 pieces, the absolute maximum being 3000 pieces. In fact, the forging die used in these tests was not entirely new, as it had already been used for forging 1720 pieces and exhibited the usual signs of wear. With this die, it was found possible to produce almost 6000 forgings heated in a lithium atmosphere before the die was completely worn. Such an increase in forging capacity is by no means exceptional, inasmuch as increases up to 400% have been reported in the literature. The reasons for these increases in forging capacity are partly due to the absence of scale on the surfaces of the blanks and partly to the lubricating effect of the protective film formed by the lithium vapour.

A microsection of a specimen heated for 6 min in a lithium atmosphere at 1150°C is shown in Fig. 3a, and of a similar specimen under the same conditions, but in a normal furnace atmosphere, in Fig. 3b. The different depths of decarburization can clearly be seen, the speci-

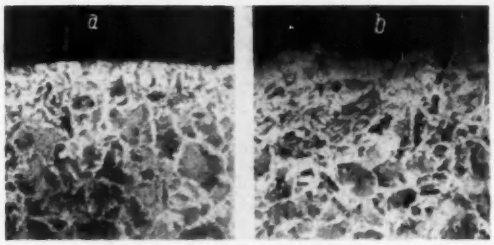

Fig. 3. Surface decarburization of a clutch lever heated for 6 min at 1150°C in (a) a lithium atmosphere, and (b) a normal furnace atmosphere. (× 145)

men heated in a lithium atmosphere being decarburized to only half the depth of that with the specimen heated under normal conditions. The depth of roughness in the two specimens should also be noted.

As many forgings are heat-treated, the investigations were extended to determine whether, and for how long, the protective layer can protect the metallic surfaces against scale formation during subsequent heat treatment, without the influence of lithium vapours. For this purpose, clutch levers heated both in lithium atmospheres and in normal annealing atmospheres were subjected to heat treatment for periods of 15, 30, and 60 min in an electric furnace at 860°C. It was found that levers previously heated in lithium atmospheres did not develop appreciable scale formation in heating periods of up to 60 min, while longer heat-treatments tended to induce considerable scaling. After cooling of the parts, most of the layer tended to drop off, so that further protection during repeated heatings cannot be expected.

Insofar as economical considerations are concerned, the cost per forging was found to be slightly increased, but this additional cost was compensated by the elimination of scaling losses and by the increase in the total capacity of the forging-die plates. As a result, savings in forging-die material, wages, and time lost in the exchange of tool parts were effected.

Other advantages are that adhesion (baking) of loose scale to the hearth of the furnace is avoided, as also is the need to descale heated blanks and to remove scale left in the forging dies. No special equipment is required for these purposes, and, in fact, the entire process is rendered more fluid, with a corresponding increase in production. In the case of certain forgings, subsequent pickling treatment can be eliminated or considerably shortened.

It should be noted that the economy effected by the above considerations is not limited only to actual forging operations, but extends quite considerably into the subsequent stages, such as chipping treatments, with decreased wear of chipping tools and a corresponding increase in their capacity. Furthermore, owing to the excellent surface condition produced, machining tolerances can be reduced to a minimum.

U.S.A.

Magnetic-Flux Gas-Shielded Arc Welding

By J. E. DATO. (From *Iron and Steel Engineer*, Vol. 35, No. 9, September 1958, pp. 160-165, 13 illustrations.)

ALTHOUGH there are many good processes for welding carbon steel, there is a wide field that is not adequately covered by these methods, from the standpoint of highest possible quality at the lowest possible cost, this field lying between manual-covered electrode welding and fully automatic production units. To fill the need, a magnetic-flux gas-shielded arc-welding process, producing high-quality welds in mild steel at greater welding speeds and lower welding costs than covered electrodes, has been developed.

Essentially, the components of magnetic-flux gas-shielded arc welding are bare welding wire, magnetic flux, and carbon dioxide gas, these components being shown schematically in Fig. 1. During welding, the flux, propelled in a gas stream, and the wire are fed simultaneously to the torch. At the torch nozzle, the welding current flowing through the wire establishes a magnetic field which attracts the magnetizable flux to the wire (Fig. 2). As a result, the electrode or wire is " flux-coated " as it enters the arc. The flux performs three main functions, i.e., it stabilizes the arc, refines and protects the weld puddle, and controls weld contour and coalescence. Besides conveying the flux to the torch, the carbon dioxide also provides supplementary shielding and, in combination with the flux, gives desirable arc characteristics. These characteristics are similar to those of covered electrodes and can be very readily learned by the average welding operator. In fact, since the wire is fed automatically, manual-skill requirements for down-hand welding are less than with covered-electrode welding, and the process can be learned more quickly.

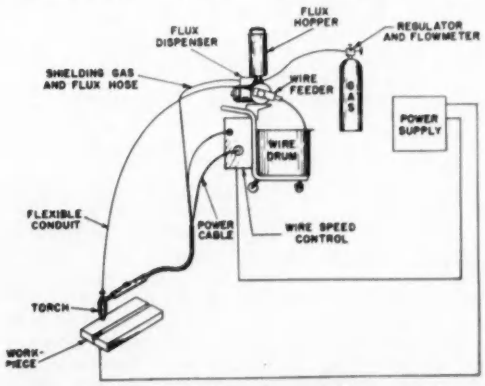

Fig. 1. Schematic layout of the components of the magnetic-flux gas-shielded arc-welding process.

Current densities are generally higher than with covered electrodes. Metal transfer is of a " spray " type, and there is very little spatter. The small amount of spatter occurring is not tenacious and can readily be removed by wiping or light brushing.

The flux contains 30% iron powder, which is bonded to the flux particles. The iron powder, which is very fine (200-mesh), ends up in the deposited weld metal. The flux removed from the top of the weld that solidifies in the completed weld does not contain substantial amounts of iron left in it.

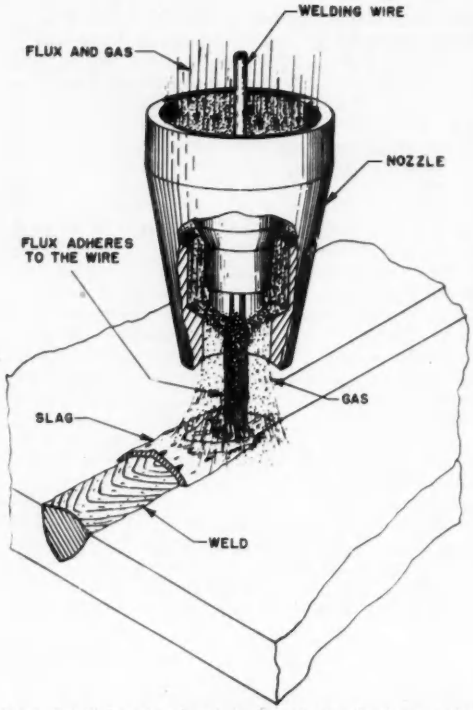

Fig. 2. Detail of nozzle and workpiece, snowing how flux is attracted to the wire by the magnetic field.

The equipment used is somewhat similar to other semi-automatic welding machines. The coiled wire is contained in a cardboard drum and is fed to the torch by an electronically controlled drive unit, which is directly coupled to the flux dispenser, so that the flow of flux is always proportional to the wire feed, the desired flux-to-wire ratio being set on the flux dispenser. The bare wire is fed through a 16-ft flexible conduit, and the flux, metered to the proper proportion, is fluidized by the carbon dioxide gas stream and conveyed through a hose to the welding torch. Fig. 3 shows the flux dispenser and the method of metering, the magnetic wheel being directly connected to the wire-feed drive unit. The wire, flux, and gas are brought together for the welding operation through the air-cooled torch. A constant-potential d.c. power source is generally used ; however, conventional drooping-characteristic power supplies can be used for many applications, particularly when high welding current densities are used. The process can be used with a.c. equipment, but operation is not as stable as with d.c. equipment, and more spatter is obtained.

Welds can be made in all positions with the new process, but lower current densities and greater operator skill are required when welding in the vertical and overhead positions, as compared with flat and horizontal welding. Two wire sizes, $\frac{3}{32}$ and $\frac{3}{64}$ in. in diameter, cover a wide operating range, and the equipment is designed around these two sizes.

For welding in the flat and horizontal positions at high current densities, $\frac{3}{32}$-in. diameter wire is used in a range of approximately 350 to 500 A d.c., reversed polarity, with a flux-to-wire ratio of 1 : 2. These conditions are particularly successful in fillet welding, high speeds being obtained with no undercutting. The process will also give excellent results with butt welding, a double-bevel edge preparation being generally recommended.

On all-position welding, $\frac{3}{64}$-in. diameter wire is used with welding currents varying from 125 to 250 A d.c., reversed polarity. Flux-to-wire ratios are in the range of 0·3:1 to 0·6:1.

With regard to the question of operator fatigue, it is true that a standard electrode holder is lighter than it is in the case of the new process. Consequently, while operation in the down-hand position is not a great problem, weight does become of importance in the vertical and overhead positions. However, work is being carried out to produce a lighter, more easily handled piece of equipment, and it is believed that a satisfactory new torch has now been developed.

Insofar as the use of the equipment in maintenance operation is concerned, some adjustments must be made. However, the current range is reasonably wide and is not too critical. Also, gas flow is more or less constant, once it has been set, while flux ratios remain constant with changes in wire-feed speed.

Welds made with the new process on a variety of steels have exhibited excellent quality and have easily met relevant radiographic requirements. In addition, welds subjected to standard, side, root, and face bend tests have been found to possess satisfactory soundness and bending qualities.

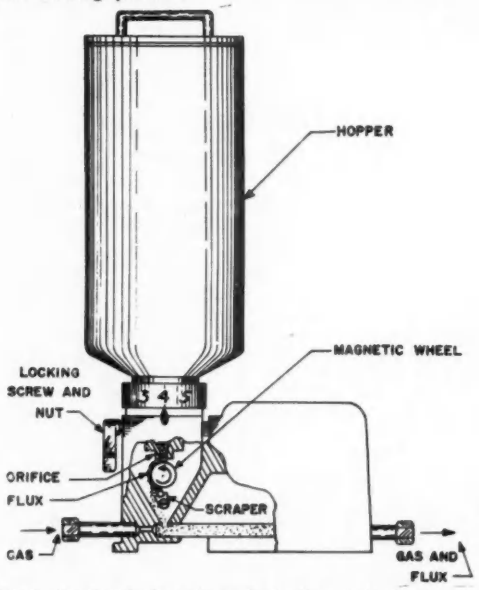

Fig. 3. Detail of the dispensing mechanism for metering flux into the gas stream.

Many applications are being found for the process. Its advantages of high speed, ease of operation, high current input, limited spatter, and high quality make it especially adaptable to operations such as the fabrication of earth-moving equipment, oil-field equipment, pipe welding, field storage tanks, casting repair, bridge girders, and railroad-car fabrication. In short, while it should by no means be regarded as a completely universal method of welding, it definitely lends itself to many applications and, if properly applied, produces high-quality welds economically at a high deposition rate.

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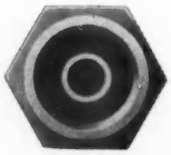

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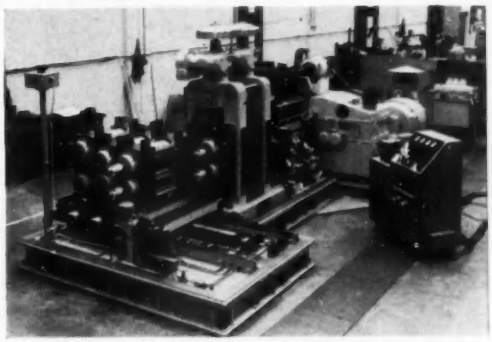
British Industrial Developments

Rolling Mill for Processing Nuclear Fuel Elements

In general, materials used in the construction of nuclear fuel elements must be handled with extreme care, and very rigid safety regulations are laid down with regard to hazards engendered by exposure to radioactivity, including inhalation of dusts. The processing of nuclear fuel elements of different shapes and configurations therefore gives rise to a number of problems. With a view to overcoming these problems, a unique rolling mill, incorporating a remotely operated roll-changing mechanism, has been designed and manufactured by Albert Mann's Engineering Co. Ltd., of Basildon, Essex, and is being installed in one of the metal-working laboratories of the Commissariat à l'Energie Atomique in France.



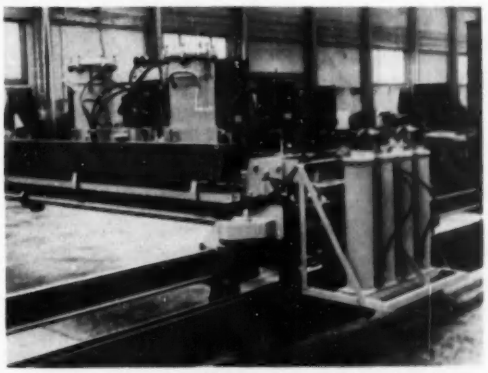
The mill is a Stanat/Mann 2-high/4-high combination unit, with a diameter of 10 in. and a face width of 14 in., and has a 600,000-lb maximum rolling load capacity at a speed of 100 fpm. The roll-changing mechanism is remotely actuated from a control desk, selection of the particular roll assembly required for a given rolling operation being effected by a switch. Operation of a push-button gives rises to an electro-hydraulic sequence, comprising (1) disconnecting the screwdown from the top roll, (2) elevating the screwdown to a position which will accept any roll configuration, (3) withdrawing the jibs retaining the chocks in position in the mill housings, (4) withdrawing the roll assembly onto the roll carriage, (5) supporting the universal spindles during withdrawal of the roll assembly, (6) indexing the roll carriage to line up the roll assembly selected, (7) adjusting the universal spindles to cater for the roll centres of the new assembly, (8) entering the roll assembly into the mill, (9) locking the chocks into position by the jibs, and (10) collecting the new top-roll assembly by the screwdown mechanism, with prevention of the application of any major screwdown pressure when there is no material between the rolls. The rolls are adjusted by means of a 2-hp infinitely variable speed motor through a double worm reduction to the screwdown spindles, a magnetic clutch enabling individual adjustment of each side of the mill to take place. Screwdown speeds are variable from 0·18 mm/sec for cold rolling, up to 2·6 mm/sec for hot rolling.

A comprehensive system of instrumentation is fitted, allowing left-hand or right-hand roll pressure, or the sum of both, to be read at the control desk. These pressures are measured by load cells situated between the screwdown and the top-roll chocks. Measurement can also be made of the upper roll-neck torque, lower roll-neck torque, and the sum of both. These are measured on the universal driving spindles by strain gauges, the signals being transmitted via slip-rings and brushes mounted on universal joints. A 2-pen high-speed recorder is provided at the control desk for the recording of roll pressure and roll-neck torque.

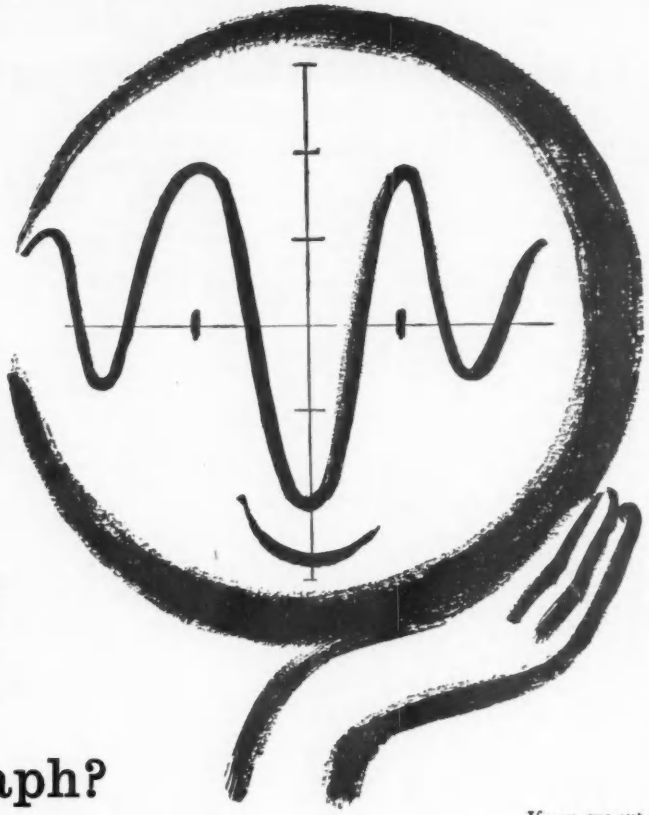
The control equipment, developed by Mann's Electronic Laboratory, is extremely flexible in operation over the required speed range, shows economy in capital cost over conventional methods of control, and is based on a special new technique of pulse-controlled thyratrons. Owing to the extreme compactness of the electronic components, a very great space saving for the equipment itself and for spares storage can be obtained. Thus, the control console not only incorporates the variable-speed control for the 100-hp mill drive, but also the 2-hp variable-speed screwdown-motor control, all the relays, etc. associated with solenoid control of the hydraulic circuits, and also the amplification and recording required by the torque and screwdown pressure system. Very high orders of speed stability and control can be obtained with this equipment, permitting close automatic control of tension, and making the introduction of programme control comparatively simple.

Large Oxygen Cutting Machine for Stainless Steel

With a cutting area measuring 27× 42 ft, a special-purpose machine, constructed by Hancock & Co. (Engineers) Ltd., of Croydon, has recently been installed in the Park Works of the English Steel Corporation Ltd., of Sheffield, and is believed to be the largest oxygen cutting installation in the world. The machine, designated model COT I, is being used for the powder cutting of stainless-steel slabs up to 45 in. in width and 6 in. in thickness, and weighing up to 12 tons, according to length. Cutting speeds are of the order of 7 ipm with a cutting oxygen pressure of 75 psi.



On the main rails of the machine, 60 ft in length, are mounted two driven gantries, each spanning 30 ft and giving a cutting width of 27 ft. On each gantry is mounted a heavy-duty driven carriage incorporating a pair of iron-powder dispensers of large capacity and two burners on an outrigger, these being capable of cuts up to 48 in. apart. Each gantry is also equipped with an additional independent non-driven carriage with a single burner. Hose-handling arrangements are particularly unobtrusive, and the services to each driven carriage



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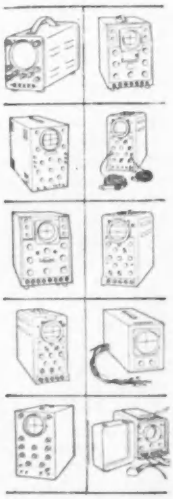

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include oxygen, acetylene, compressed air, and electric power cable. These are contained in a stainless-steel spiral which lies neatly at all times in channels fixed to the side of each gantry and alongside the main rails, coiling and uncoiling smoothly during the traversing motions.

On the driven end of each gantry a cradle is fitted, to carry the air driers for the powder dispensers, as shown in the illustration. Each dispenser has its individual pair of driers. At any given time one drier of each pair is in operation, while the other is being reactivated. Humidity indicators are fitted, and the necessity to switch over to the other drier is indicated by colour changes. The powder cutting attachment on each of the burners is not of the concentric-nozzle type but consists simply of a small-diameter tube. When cutting, the tube precedes the burner.

In operation, the slabs are generally lined up for cutting parallel with the main rails of the machine, and all cuts are transverse, as the long sides do not normally require trimming. One of the gantries is brought into position over the " ingot-head " end, and the driven carriage then traverses, making two trimming cuts about 20 in. apart, whilst the other gantry is used to remove the " bottoms ", all cuts being made simultaneously. When taking the two trimming cuts, the burner nearer the end of the slabs leads slightly, to ensure that it completes its cuts before the other burner. Trimming procedure is continued until sound metal free from ingot-head unsoundness is reached, and the off-cuts go for remelting. The sound slabs are then cut into lengths of about 6 ft.

High-Altitude Test-Plant Equipment for Aircraft Engines

Power-measuring equipment of Heenan & Froude design is used for engine test cells at the two new high-altitude plants of Rolls-Royce Limited, and is capable of operating satisfactorily and giving readings of high accuracy at temperatures between —20°C and + 350°C and at pressures varying from full vacuum to 75 psi. One cell is equipped for turbo-jet engines and the other for either turbo-jet or turbo-propeller types. The two thrust-measuring stands are built onto sub-frames attached to the circular stainless-steel test-cell vessels. The connections incorporate trunnion bearings with pins in spherical housings to prevent distortion due to cell expansion and contraction. The moving portion of each thrust stand supporting the engine is suspended by four spring-steel plates. The maximum thrust catered for is 20,000 lb, with a negative thrust of 2000 lb.

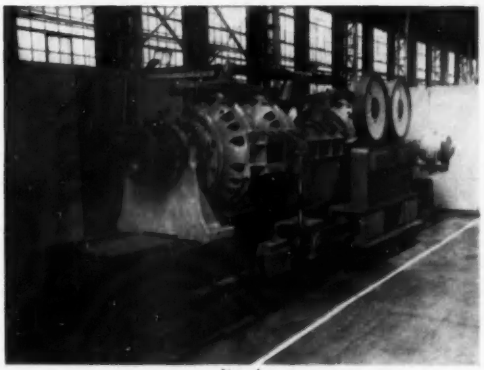

Fig. 1.

The measuring equipment in each case consists of a weighing machine connected to the thrust stand by mechanical linkage. The weigher has two dials, one reading from —2000 to + 5000 lb, and the other from 4000 to 20,000 lb, change-over from one dial to the other being automatic. The weighing machines are located alongside the steel cells, and repeat dials are installed on the remote engine-control panels. Pointer movement from one to the other is transmitted electrically. Thrust-checking gear consists of mechanical linkage, reduction levers, and weights, the latter being applied outside the cell. Seals are provided at points where the linkage passes out of the cells. The engines are placed on the thrust stands already rigged on an adjustable dolly with under-frame.

Additional facilities in the cell designed for testing turbo-propeller engines consists of dynamometers, transmission shafting, and engine supports (Fig. 1). For torque absorption and measurement, two Heenan " Dynamatic " dynamometers, Mark VI C, are mounted in tandem outside the cell, and, when operating together, can deal with powers up to 6000 bhp at speeds from 800 rpm upwards. Torque-measuring equipment consists of a weighing machine mounted alongside the dynamometers, with mechanical linkage from the torque arm. Repeat dials are mounted in the control room. Torque-checking gear is of the lever-and-weight type.

Fig. 2.

The transmission shaft for full dynamometer torque couples the engine to the dynamometer and comprises a central main shaft through the end of the steel cell, with a gear-toothed cardan shaft at each end. To allow for differential expansion between the cell and the transmission system, long central shaft bearings and adequate float in the gear-toothed couplings are provided. A stainless-steel tube encasing the central shaft is fitted with seals to prevent air leakage. Owing to the varying conditions of pressure and temperature along the length of the main transmission and cardan shafts, two lubricating systems are provided, one serving the dynamometer end and the other the engine end. Each system consists of an oil storage tank, main circulating pump, filter, heat exchanger and the necessary pipe work, and valves. Scavenge pumps are provided in the oil return lines. The propeller-turbine engine is mounted in a steel framework, carried from a vertical bulkhead inside the cell.

For both cells Heenan & Froude have also supplied the control desks, engine controls, and instrumentation. Part of the main control room, showing one of the two control desks, is illustrated in Fig. 2.

Molybdenum Disulphide Powder

While it is true that the use of molybdenum disulphide as a solid lubricant capable of withstanding extremely high pressures is well known, it is also true that the particle-size reduction of this material is by no means an easy problem. Thus, for example, ordinary milling processes cannot be used, as they cause oxidation, leading to the formation of molybdenum trioxide, which has no lubrication value at all. Similarly, while it is possible to reduce molybdenum disulphide particles in liquids, or in

Q

A

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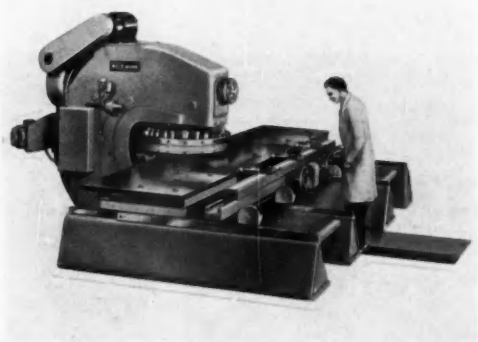
ball and roller mills (the finest powders generally obtainable have average particle sizes of $\frac{3}{4}$ to 3 microns), it has often been found that such quasi-colloidal dispersions are not as effective as the flake materials, as there appears to be a loss of some of the advantageous properties of the material, possibly also due to oxidation.

It is now reported, however, that, by means of a quasi-air-flotation method, K. S. Paul (Molybdenum Disulphide) Limited, of London, N.W.10, have produced on a commercial basis a molybdenum disulphide powder with an average particle size of from $\frac{1}{4}$ to $\frac{1}{2}$ micron. Trial production batches have shown considerable consistency of results, and the flake-like structure of the material has been maintained. In addition, an important point is that a change in pH-value has not been detected, as compared with standard and micronated particle-size materials.

Double-Headed Keyway and Cotter-Hole Cutting Machine

Intended primarily for railway-locomotive work and capable of milling parallel or taper cotter slots in a variety of components, a double-headed keyway and cotter-hole cutting machine, designated size " 1 ", recently introduced by Adcock & Shipley Ltd., of Leicester, can handle keyways up to $1\frac{1}{4}$ in. in width and up to 12 in. in length.



Basically, the machine consists of a substantial bed which carries a double table, reciprocated longitudinally on slides by an adjustable crank disc coupled to the table by a cross-head. The top table can be oscillated by another eccentric disc when it is necessary to cut taper cotter slots. This second eccentric disc is mounted at the rear of the machine and is connected to the top table on the left-hand side by a suitable link. On either side of the main bed are two cutter heads, which are traversed inwards on suitable Vee slides by the feed mechanism. By adjusting the eccentric disc and the cross-head, the length and position of the keyways or slots to be cut in the shafts can be determined. Each adjustment is provided with Vernier scales for setting purposes. For taper cotter slots, the throw of the eccentric disc controlling the angle of taper is also adjustable. In order to maintain a set feed rate, compensating eccentrics are provided in the drive to the reciprocating crank disc of the table, thereby maintaining a reasonably constant traversing speed on the table motion. The rate of reciprocation of the table can be varied by slip gears from 1·6 to 20 single strokes per minute.

The cutter heads carry the cutter spindles, which run in three ball and roller bearings. Each spindle is supported by a pair of preloaded precision angular contact bearings at the front and a roller bearing at the rear. They are arranged to take collets from $\frac{1}{4}$ in. to $1\frac{1}{4}$ in. in diameter. Six spindle speeds, from 227 to 1200 rpm, are provided, the final drive being taken to the spindles through a spline shaft. Infeed of the heads at the end of each stroke is by means of a ratchet-and-pawl arrangement operated by a cam on the vertical shaft, which drives the reciprocating crank disc of the table. The amount of infeed is adjustable in small increments in the range between 0·005 and 0·050 in. per stroke.

The design of the mechanism controlling the infeed is such that it can all be operated from the front position, provision being made for operating one head alone or two heads simultaneously, when cutting double keyways. In addition, a special arrangement for cutting slots is provided, whereby the feed mechanism to the rear heads reverses, thus maintaining a set distance between the cutters until the centre web has been cut out. The feed then stops, and the heads can be wound back to their dead-stops by hand. The cutter heads are also provided with hand adjustment for setting purposes, etc.

Automatic Gear-Processing Assembly Line for Layshafts

Believed to be the only one of its kind in Europe, a fully automatic gear-processing assembly line, intended to speed up the manufacture of layshafts in motor-car gearboxes, has been developed and was recently demonstrated by Churchill Gear Machines Limited at their Blaydon-on-Tyne Works. This link line or transfer assembly is 175 ft in length and consists of 25 standard machines, manufactured by a number of different companies, these machines being linked together with transfer and loading mechanisms, conveyors, and automatic " hands " designed by the company. Only two types of automatic machine loader and two types of " between-machine " conveyor mechanism are used.

The automatic line commences with a bank of five Churchill rigid hobbers. To achieve the production required, two of the five machines hob the fourth-speed gears, two machines hob the third-speed gears, and the remaining machine hobs the first-speed gears. The layshafts introduced to the conveyor move to the first of the two hobbers for the fourth-speed gear and build up a small storage bank of gears. Further components are deflected to by-pass the bank and feed the second machine, again forming a small bank. The first component to reach the machine moves into a preload arm, operating a micro-switch which signals the start of the machine cycle, when the preload arm slides the component across the conveyor to the " pick-up " station, where the transfer arm grips it and then lifts and transfers it to the cutting position. After a predetermined time delay, the preload arm returns to the centre of the conveyor, allowing the next component to move into position ready for preloading when the machine has completed the full cycle.

After gear cutting, the transfer arm returns the layshaft to the conveyor on the inner of three tracks into which the conveyor is divided, and along which it moves to by-pass the next machine, but to be diverted back into the centre track for feeding the next two machines. The outer track is used by the components which by-pass a storage bank to supply the next machine. A gate mechanism, electromagnetically operated, prevents them from moving along the inside track to pass a machine when the machine is being loaded.

After leaving the bank of hobbing machines, the layshafts pass to the end of the conveyor, where they turn over under gravity onto horizontal guides on which they roll to the Churchill " Gear-Wash " for cleaning before gauging. The gear-wash uses a hot chemical high-pressure spray system and removes all cutting oil and swarf. An air-jet system dries the layshafts before they leave the gear-wash to roll into a storage bank to await gauging for size, run-out, and lead on all three hobbed gears, by means of Churchill " Auto-Gauges ".

When gauging is complete, the head and tailstocks retract and allow the layshaft to roll to the next operation, or in the case of a reject, into a reject chute. When a

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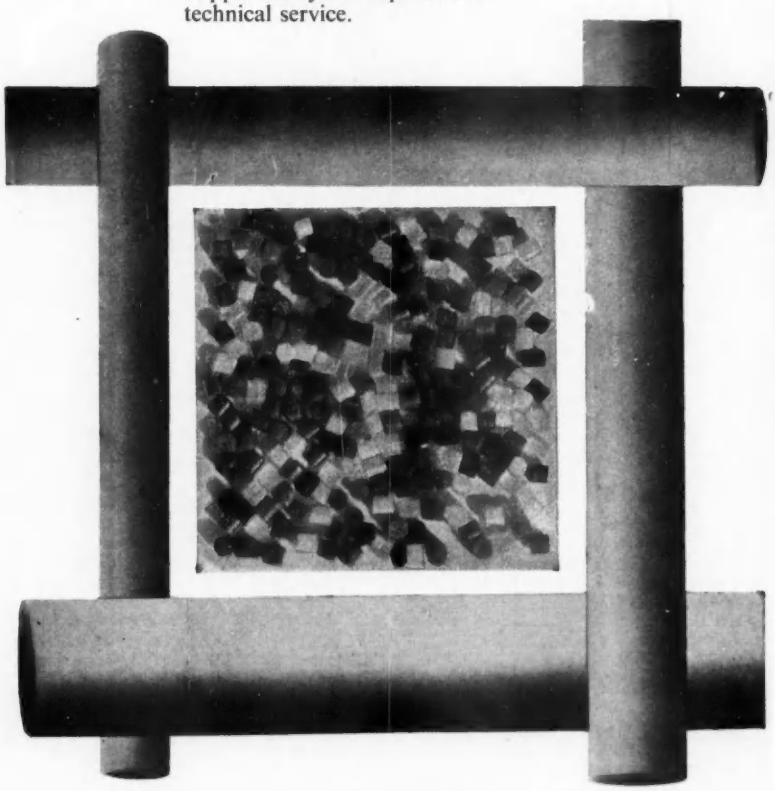

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preselected number of components has passed into this chute, an electrical signal is passed back to the machine involved to hold up production pending investigation.

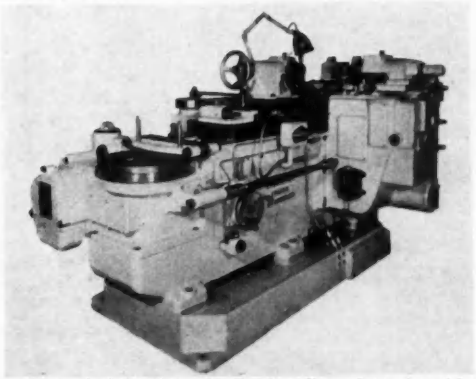
After gauging, the layshafts are turned over to the vertical-axis position onto a conveyor, feeding three Fellows-England high-speed shaping machines. This conveyor, with its selector guide mechanisms, is identical to the one feeding the hobbing machines, and allows each machine to operate individually, supplying a storage bank to each machine.

The layshafts are next submitted to another washing and gauging operation, rejects again being passed to a reject chute. They are then passed to two Churchill gear rounders and subsequently to three Churchill gear chamferers, which remove the acute edges of the helical gears on both sides of the teeth, using rotary chamfering tools. After chamfering, the layshafts are discharged through the machine column and elevated to a chute feeding four Churchill " Red Ring " G.C.U. shaving machines, provision being made in the line for an automatic brushing machine.

After leaving the shaving machines, the layshafts are given another wash, followed by gauging with heads to gauge all four gears. The layshafts now roll to a bank supplying a grinding machine, on which the outside diameters of the three helical gears are ground by a formed wheel fitted with automatic wheel-truing compensation. This machine, supplied by the Newall Engineering Co., of Peterborough, is fitted with a Newall design of pneumatically operated loader, the first of its type. The layshaft is gripped, lifted, and then transferred by the arm to the grinding position. After grinding, it is released and rolls down a curved chute to a standard section of conveyor, where the automatic gear line ends. The layshafts are now ready for transfer to heat treatment.

Heavy-Duty Turret Punch Press

A new heavy-duty turret punch press, designated Model R. 61, of 80,000-lb punching pressure and a punching capacity of 6 in. diameter for mild-steel plate of ½-in. thickness and 1¼-in. diameter for ¾-in. thickness, has been added to the range of British Wiedemann turret punch presses marketed by Dowding & Doll Ltd., of London, W.14.



The principle of standardized tooling adopted enables any tool set to be instantly indexed to the working position in rotatable turrets, and the operator to change from job to job without loss of time. Rotation of the upper and lower turrets is synchronized and, in the working position, the punch is in perfect alignment with the corresponding die. The turrets are positively located, and the electrically operated press cannot be tripped between stations.

The turrets, rotated by a geared ½-hp motor and controlled from the operating position, can be supplied with 20, 24, or 28 punching stations. Tools of any shape or size can be mounted, including a range of round tools, and all tools can be easily changed. The press has a throat depth of 33 in. and a ram stroke of 1¼ in., and is driven by a 3-hp motor.

During operation, the plate to be pierced is positioned between the upper and lower turrets, with its front edge in contact with locating pads and its right-hand edge against a stop. It is then clamped, and the two edges of the plate, or datum lines, are positioned relative to the punch centre-line by two handwheels, which operate circular-pitch racks and pinions, one controlling the lateral and the other the lengthwise setting. The precise distance from the edges of the plate to the punch centre-line can be read from direct-measuring indicators positioned over each handwheel.

Special Analogue Computer for Motion of Railway Trains

An interesting example of a special-purpose analogue computer, built by Messrs. F. C. Robinson & Partners Limited to the designs of Professor E. Bradshaw, of Manchester University, automatically predicts the motion and energy consumption of railway trains. The information supplied to the computer includes the tractive effort and power demands of the locomotive, the resistance to motion at different speeds, and the gradient profile for the route travelled. This information is inserted in the form of curves or punched tape and is continuously " read " by the computer as the speed and distance travelled vary.

The working forces are read continuously, summed algebraically, and fed to an integrator which evaluates velocity. The velocity is again integrated to obtain distance. The integrators take the form of the familiar induction energy meter, as used for the metering of domestic electrical supplies. At each stage, velocity and distance outputs are employed to control the outputs of velocity-dependent and speed-dependent quantities used in the computation. Velocity is automatically plotted to a base of distance or time.

Experience has shown that information on train motion can be obtained at least ten times more quickly by such an analogue computer than by hand calculation. Furthermore, analogue devices of this kind have the advantage that it is possible to see the computing process in operation and to stop the process at any desired stage, so as to make changes in conditions, an example being the freedom to start coasting or braking at any stage.

Copy Nibbling Machine

It is announced by F. J. Edwards Ltd., of London, N.W.1, sole agents in the U.K. for the range of shearing and nibbling machines manufactured in Germany by Trumpf & Co., that these are now designed for use as copy nibblers. With the new copy nibbling machine, it is possible to produce, with a template clamped to a template table, sheet-metal blanks of any desired shape, both internally and externally, without previous tracing or marking out. A drawing or sketch of the original can be used in place of the template, and it is unnecessary either to hold by hand or to turn the sheet during the working procedure. A further application of the machine is for producing right-angle-shaped blanks from sheet metal—using rules on the carriage guides.

In operation, the template shape is followed with a manually operated pointer, which is adjustable on the copying arm to suit the size of the original. This movement is transmitted to the material carriage, which has a completely free horizontal movement, both left to right and forward and backwards, and the shape is thereby copied in the material by the nibbling punch. The carriage is supported on accurate roller guides for all movements. All kinds of metal can be cut, e.g., copper, brass, alumin-

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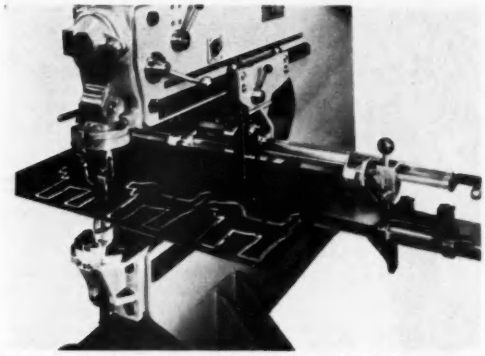

ium, duralumin, and stainless steel in a limited capacity. Other materials such as plastics, hardboard, and similar soft, but firm, substances can also be cut.

The process is employed to best advantage when producing a large number of identical shapes which do not necessitate the provision of expensive punching tools. With a view to saving material, the plates, depending on the required shape of the blanks, can be placed one upon the other.

High-Temperature Phosphonitrilic Polymers

In recent years, the phosphonitrilic series of inorganic polymers has attracted increasing attention, largely as a result of the demand for high-temperature-resistant materials, e.g., for use in rockets. It is now announced by Albright & Wilson (Mfg) Ltd., of London, S.W.1, that, as a result of the success of the initial stages of their research project into the nature and properties of phosphonitrilic chlorides, it has now become commercially practicable for them to separate the trimer and the tetramer from the crude mixture of linear and cyclic polymers. Albright & Wilson are thus the first chemical manufacturing company in the world to announce that they can separate the polymers on a commercial scale.

Sample quantities of pure trimer and tetramer are already available, and greater quantities will be available shortly. Incidentally, the phosphonitrilic compounds have several similarities to silicones (the manufacture of which in the U.K. was also pioneered by Albright & Wilson), and the company are hopeful that a wide range of heat-resistant materials, in addition to other products, will be developed from them.

New Method of Applying Ceramic Coatings to Metals

Because many components may be too large, too small in cross-section, or too complex to be made in solid ceramics, they must often be constructed in less suitable materials. It is now reported, however, that many of these limitations on size and design have been overcome by a new method, developed by the United Insulator Division of The Telegraph Condenser Co. Ltd.,of Chessington, Surrey, of applying coatings of a range of ceramic materials manufactured by this company on steel, brass, copper, aluminium, and other metals, and also to glass and even plastics. The ceramic material is specially prepared, heated to a temperature above 3000° F, and then applied at high pressure to the component, which is itself kept cool. The thickness of the coating can be only a few thousandths of an inch, or it can be built up to at least $\frac{3}{4}$ in., as required.

The range of ceramics adopted for these coatings, designated " Unikote ", includes " Unilator ", a gem-hard ceramic which can be made electrically insulating or conductive, as desired ; " Unilatum ", a high-temperature, high-insulation ceramic, which is also extremely hard ; and " Unilain ", a heat and electrical insulator. All these materials are resistant to wear, heat, moisture, and chemicals. Other materials, still in the stage of being perfected, include high-permittivity dielectrics and piezoelectric ceramics.

It is stated that the cost of these ceramic coatings is small, compared with that of the replacements they save, and is considerably less in many cases than that of an equivalent part constructed in solid ceramic, even if it were possible to make it. Applications include their use in bearings, pump impellers, mechanical seals, R.F. induction-heating coils, jet- and rocket-engine exhausts, and crucible and ladle linings.

Horizontal-Type Honing Machine

A new British-built honing machine, the " 150 Hydrohoner ", suitable for both batch and high-production honing, is now being manufactured by A. A. Jones & Shipman Ltd., of Leicester, under the provisions of a licence from the Micromatic Hone Corporation, of Detroit, Michigan. Intended to fill the gap between the large mass producer and the smaller shop, the machine provides for economical automation and combines versatility with a standardized, compact design.

The machine is built as a horizontal-type unit, with a stationary bridge to accommodate work fixtures and optional equipment. Change-overs from one job set-up to another are simplified, and the addition of automatic work-handling devices is an easy matter. The spindle is mounted on a reciprocating, hydraulically actuated carriage, the adjusting head being manually operated. The table measures 17 × 16 in., and the machine has a 12-in. stroke and a $\frac{1}{2}$-in. work-diameter capacity.

A feature of the basic design of the " 150 Hydrohoner " is that it breaks down the functions of larger machines into the stages necessary for full automation, it being possible to add each stage to the basic machine at any desired time. Thus, the basic machine includes hydraulic initial tool expansion and collapse, an adjusting head for manual tool-feed expansion and stone-wear compensation, a variable-speed belt drive for spindle rotation, and provision for gravity coolant drainage. If desired, however, it is always possible to add automatic hydraulic feed control and stone-wear compensation, automatic sizing, and automatic work-handling devices.

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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Strain-Ageing of High-Carbon Steels.

By F. DE KAZINCZY. (From *Jernkontorets Annaler, Sweden*, Vol. 142, No. 8, 1958, pp. 515–535, 8 illustrations.)

THE purpose of the investigation described in this paper was to examine the mechanism governing improvement in the elastic properties of high-carbon steels during annealing in the temperature range of 150° to 300°C. The two possibilities considered are strain-ageing and relief of internal stresses.

It is shown that the time-temperature relationship of change in mechanical properties leads to the activation energy of carbon diffusion according to the Cottrell-Bilby model of strain-ageing, provided that proper attention is given to the increasing solubility of carbon in alpha-iron with increasing temperature. Microstresses, calculated from X-ray line broadening, decreased in the investigated temperature range by only 10%, i.e., by an amount which would be expected if strain-ageing occurs. Body stresses decreased somewhat more, but the temperature dependence of their relief was different from the temperature dependence of the change in mechanical properties. It was therefore concluded that the primary mechanism is strain-ageing.

Ageing occurred, compared with mild steel, only after a considerable time delay, and it is shown that the delay increases with carbon content, particularly with more than 0·6 to 1·0% C. A similar time delay was observed if the specimens were tested in a direction different from that in which they were deformed prior to ageing. A suggested explanation of the time delay is based on the assumption that those dislocations first to acquire a solute atmosphere would not contribute to further slip, whether pinned or not. Solute pinning is considered to develop first at pile-ups with large stress fields. Qualitative descriptions are included of ferrite-path effects, and of the influence of changes in straining direction on the number of " inactive " pile-ups, and thus on time delay.

Strength at Elevated Temperatures of Aluminium and Certain Aluminium Alloys.

By N. P. INGLIS. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, October 1958, 10 pages, 12 illustrations.)

As described in this paper, short-time tensile, stress-rupture, and creep tests have been carried out on 99·5% aluminium and a number of other aluminium alloys, i.e., a 1¼% manganese alloy, a 2¼% magnesium alloy, a 3½% magnesium alloy, and a heat-treatable magnesium silicide alloy. Short-time tensile and stress-rupture tests were carried out on all five materials, but creep data are, as yet, available only for the manganese alloy and the heat-treatable magnesium silicide alloy.

For each of the five materials, a direct chill-cast billet of 7¾ in. diameter and 30 in. length was preheated and extruded through a single-hole die. In this way, rods of 1¼ in. diameter, each approximately 110 ft long, were produced, but from these lengths only the middle 40 ft were used for the tests. With the exception of the magnesium silicide alloy, all subsequent tests were carried out with the materials in the extruded condition, no heat treatment being involved. However, the magnesium silicide bar was cut into a number of short lengths, which, prior to machining the testpieces, were solution-heat-treated at 525°C, water-quenched, and artificially aged for 18 hr at 160°C.

Short-time data cover a temperature range of 20° to 250°C, the stress-rupture curves, which mostly extend up to 10,000 hr, relating to temperatures of 100°, 150°, 200°, and 250°C. Creep tests, a number of which were taken into the tertiary stage, were carried out at 200° and 300°C for the 1¼% manganese alloy, the temperatures employed for the magnesium silicide alloy being 100°, 150°, and 200°C.

Stress-temperature curves are plotted which enable a direct comparison to be made of the effect of temperature on rupture strength for specified amounts of time, and the paper includes a fairly detailed report of the effect of time, stress, and temperature on microstructure, and discusses the types of fracture encountered.

Investigation into Elastic-Sheath Pressure Cables.

By N. KLEIN. (From a paper submitted to the *AIEE Summer General Meeting and Air Transportation Conference, Buffalo, U.S.A.*, June 22–27, 1958, 24 pages, 7 illustrations.)

THE pressure in high-voltage pressure cables is usually maintained with the help of external means, such as oil reservoirs and gas-filled pipes round the cables, which considerably complicate design and mechanical functioning. For many years, ways have been sought to dispense with these external means ; however, of several patents, only one, i.e., the 3-core flat cable of Mollerhoj, has found practical application. The pressure in this cable is obtained by means of elastic deformations of corrugated metal strips and by means of insulation. Other patents propose to maintain the internal pressure with elastically stressed elements in the cable but require a rather complicated design. An exception is a very simple proposal to build the pressure cable like a non-circular, solid-type cable, replacing the soft lead or aluminium of the sheath by a highly resilient metal.

As described in this paper, theoretical investigations have been carried out on these cables, and it would appear that elastic-sheath pressure cables should be mechanically and electrically suitable for service. An equation is given for calculation of their thermal limit with good accuracy, according to which, temperature-increase limits of 70°C can be obtained for 3-core flat and also for triangular cables with various semi-hard-temper alloys, strain limits being about 0·0015 and 0·0025 respectively for the two-cable types. These cables should be especially suitable for horizontal land and submarine installations. Manufacturing, transport, and laying problems are partly new and seemingly difficult, but their great simplicity might be an inducement to practical investigations on such cables.

Experiments on the Pneumatic Handling of Powered Materials.

By L. KOVACS and J. TOTH. (From *Gep, Hungary*, Vol. 10, No. 2, 1958, pp. 59–66, 14 illustrations.)

THE development of pneumatic handling of granular and powdered materials has been very marked in recent years, and is often connected with cleaning, grading, and drying processes. Lower capital costs, easier maintenance, decrease in manpower required, and greater safety are the main advantages of this type of handling.

The failure of a mechanical handling system in a new Hungarian chemical plant induced the Technical University of Budapest to carry out experiments on the pneumatic unloading and transport of raw phosphates. A small pilot plant was built, delivering the phosphates from railway wagons through a suction head and a flex-

Electro-Heat

The ways in which electricity can be used to advantage in industry are many and varied. Some are well known but others are not known well enough. For this reason the Electrical Development Association has prepared a series of detailed data sheets on various applications which will be printed in this journal from time to time.

This Data Sheet is the first of a number devoted to electro-heat – that is, heat produced by electricity for the processing and treatment of materials. Other uses will be dealt with later on in the series.

There is an unalterable physical law that the efficiency of conversion of *electrical* energy to *heat* energy is 100 per cent. The same cannot be said of the efficiency of combustion of any solid or liquid fuel.

All the applications of electro-heat have these advantages in common:—

1 Electro-heat is clean both in regard to its application and the method of generation.

2 It can easily be controlled more precisely than any other form of heat, manually or automatically.

3 It can be brought to the job instead of having the job brought to it.

4 It permits better use of floor space and the elimination of unnecessary handling.

5 In many of the newer processes it is the only possible form of heat which can be used.

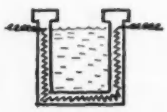
6 It often ensures a higher quality of products with fewer rejects.

7 It gives the best working conditions.

8 It effectively reduces or eliminates fire and explosion hazards.

Below will be found brief notes on some of the various methods of generating heat by electricity.

Resistance Heating



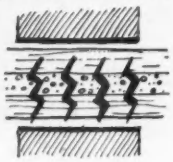
This is the best known form of electric heating. The elements provide a high resistance to the passa-e of electricity and thus heat is generated. It can be used in furnaces for melting or heat treatment of any material whether metal or not, or the resistance of the workpiece itself can cause the generation of heat.

Induction Heating

Eddy currents are induced in the surface of a conducting workpiece, heating it up. The depth to which this heating will penetrate is determined by the time it is given.

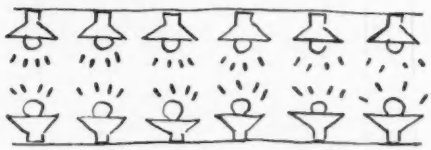
High-frequency Dielectric Heating

This form of electro-heat can be used only on non-conducting materials such as wood, plastic and rubber. The material is placed between two electrodes to which a high voltage is applied at a high frequency. This has the effect of generating heat inside the material rapidly and uniformly throughout its entire thickness.



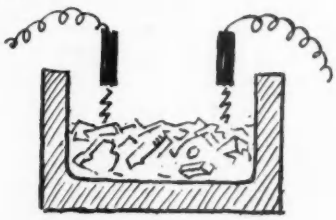
Infra-red Heating

This method employs pure radiant heat. The bulk of the radiation takes place in the infra-red portion of the radiation frequency spectrum. The heaters may take the form of reflector lamps or sheathed wire elements. The method is extremely flexible and has many uses, including paint drying and pre-heating plastics.



Arc Melting

This form of heating is chiefly used for melting steel. The diagram illustrates one method of operation. Very large charges can be melted; melting units of 200 tons capacity are now in operation.



The Application of Electro-Heat

All these methods of electric heating can be applied in almost an infinite variety of ways. Some of these ways will be dealt with in subsequent sheets.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2.

Excellent reference books on electricity and productivity (8/6 each or 9/- post free) are available—"Induction and Dielectric Heating" is an example; "Resistance Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue. 4889/2

ible hose to a cyclone. A rotary feeder was used to direct the material from the outlet of the cyclone to the delivery line whilst the used air was exhausted through a filter unit.

During the tests, 40,000 measurements were taken of the pressure-drop on the suction and the delivery side, including the frictional resistance of the cyclone and pipe walls, and the velocity of air through different parts of the equipment. It was found that the speed of the handling process was not affected by the water content of the material delivered, and the efficiency of the plant could be greatly improved by using various sizes of pipes, according to the quality of the phosphates handled. Also, pneumatic handling considerably improved the uniformity of grain size of the phosphates and made the subsequent physical and chemical processing much more effective. The experiments also supplied the necessary data for the design of full-scale pneumatic equipment for the handling of raw phosphates.

Welding of Molybdenum-Alloy Sheet.

By K. M. KULJU and W. H. KEARNS. (From *The Welding Journal, U.S.A.*, Vol. 37, No. 10, October 1958, pp. 440s–444s, 9 illustrations.)

MOLYBDENUM weldments are subject to porosity and loss of ductility at room temperature unless extreme care is exercised during welding. Poor room-temperature ductility has been found to be a function of oxygen and nitrogen in the welds. The oxygen and nitrogen content of the base metal must be small, and the welding atmosphere must be controlled to prevent, as far as possible, contamination during welding.

As described in this paper, tungsten-arc welds exhibiting room-temperature ductility were produced in commercial 0·062-in. Mo-½%Ti alloy sheet. Tensile tests were made on welded specimens between 1600° and 2200°F. The strengths of welded joints were comparable with those of recrystallized molybdenum but were significantly lower than those of wrought sheets. All specimens failed in the heat-affected zones. Nevertheless, the strengths were far superior to those of any cobalt- or nickel-base alloys currently available. The weld strength at 1800°F was 43,500 psi, decreasing to 23,000 psi at 2200°F. The zones of weakness in welded joints at temperatures above 1800°F are the heat-affected zones, and the welded joints have sufficient ductility at 300°F to permit moderate forming.

Corrosion of Metals in Tropical Environments.

By C. R. SOUTHWELL, B. W. FORGESON, and A. L. ALEXANDER. (From *Corrosion, U.S.A.*, Vol. 14, No. 9, September 1958, pp. 55–59, 8 illustrations.)

IN this paper are reported the results of eight-year tests made to determine the corrosion characteristics of ten structural steels exposed to five natural tropical environments, such as marine and inland atmospheres, freshwater immersion, and continuous and mean-tide seawater exposure, in the Panama Canal zone. Of the ten commercial-type steels evaluated, four were high-strength low-alloy steels, two were high-tensile chromium steels (one of 3% and the other of 5% chromium content), one was a 2% nickel boiler steel, one was a 5% nickel steel, and two were low-carbon steels (one copper-bearing and one unalloyed).

The corrosion rates observed were compared with existing data for the same materials in temperate zones, and the paper includes a summary of individual analyses of air samples obtained at atmospheric test sites, as well as extensive weight-loss and pitting data for the ten steels at intervals of exposure of 1, 2, 4, and 8 years. Numerous time-corrosion curves in tropical marine and tropical inland exposures are presented, considerable attention being given to the effect of low-alloy additions on mild carbon steel.

The conclusions derived from this investigation may be summed up as follows :—

(1) The corrosion of structural steels for an eight-year exposure was from 1·5 to 2·2 times higher in the tropical marine atmosphere of the canal zone than in a temperate marine atmosphere, while the tropical marine atmosphere in Panama caused 1·7 times more corrosion weight loss than the tropical inland atmosphere.

(2) No difference in type or extent of corrosion was evident between pickled and mill-scale surfaces on mild carbon steel in either of the tropical atmospheres.

(3) Copper-bearing steel was less effective in retarding corrosion in the tropical atmospheres than in temperate zones, and the corrosion of copper-bearing steel in the two tropical atmospheres was only 13 to 14% less than that of the unalloyed mild steel.

(4) The 2% and 5% Ni steels were very effective in resisting corrosion, these steels being corroded, after the eight-year exposure, from 45 to 59% less than the copper-bearing steel.

(5) The corrosion resistance of the chromium steels was comparable with that of the nickel steels, the 5% chromium steel proving slightly superior to both nickel steels in the marine exposure and appreciably better at the inland location, whereas the 3% chromium steel gave slightly better results than the nickel steels in the inland atmosphere but poorer results at the marine location.

(6) The four low-alloy steels displayed good resistance to tropical atmospheric corrosion, their weight loss over eight years being from 36 to 49% less than that of the copper-bearing steel. The difference in corrosion resistance of the four low-alloy steels was insignificant.

Experimental Investigation into the Effects of Cross Flow with Condensation of Steam and Steam-Gas Mixtures on a Vertical Tube.

By T. FURMAN and H. HAMPSON. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, November 14, 1958, 15 pages, 12 illustrations.)

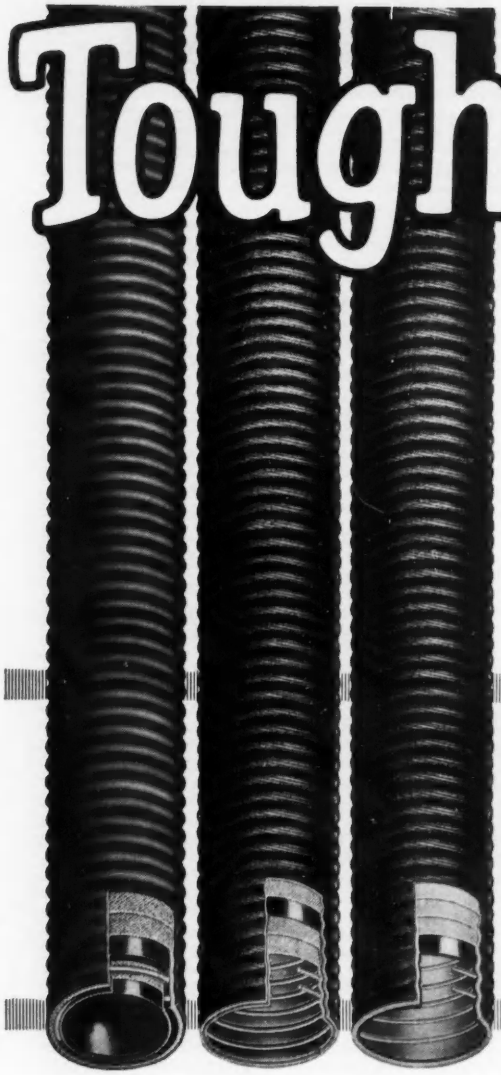
IN condensation it has been clearly shown that two "ideal" modes exist. The rate of heat transfer for the dropwise mode has been found to be several times the values obtained with filmwise condensation. The reason for the relatively low values of heat-transfer coefficients with filmwise condensation is due to the formation of a continuous condensate film over the condensing surface, through which the latent heat of vaporization has to be conducted. When non-condensable gas is present, an additional layer of gas "film" is formed next to the liquid surface, offering further resistance to heat flow. The reduction in the thickness of these films is therefore of prime importance for efficient heat transfer in condensers.

The subject of the investigation described in this paper was the magnitude of variation in heat-transfer rates with cross-flow velocities, for filmwise and dropwise condensation of pure steam and steam-gas mixtures, using a single tubular condenser. Velocities up to 150 fps and gas (nitrogen) concentrations up to 6% by weight were obtained in the test section. A double-walled duct construction was chosen. The test tube was visible from three sides, and the heat losses from the test section were made negligible by passing the returning uncondensed steam on both sides of the section. The investigation was limited to steam and steam-gas mixtures at near atmospheric pressure, condensing on a vertical tube. The range of heat loads with "pure" steam for the filmwise tests was 20,000 to 290,000 BTU/sq ft-hr and for the dropwise tests 115,000 to 320,000 BTU/sq ft-hr.

For both filmwise and dropwise condensation (except for the effect of gravity on drainage) the condensate indicated types of flow round the tube similar to those of single-phase flow, with break-away also developing in the same way as with single-phase flow.

For all gas concentrations used and with filmwise condensation, considerable improvement of the overall coefficient was shown for cross-velocities up to about 6000 lb/sq ft-hr (about 50 fps) ; with dropwise condensation, significant improvements were shown up to velocities rather higher than this value.

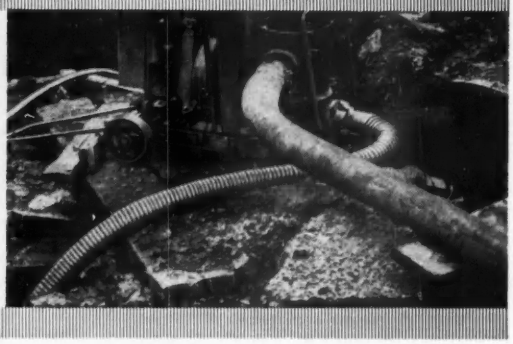
Tough



GOODYEAR HAND-BUILT HOSE for every suction job

Long service in exacting conditions has time and again proved the superiority of Goodyear Hand-built Hose for suction and discharge duties whether it be water, chemicals, foods, beverages, sand or gravel. Skilfully designed and constructed, the hose has multiple plies of high-strength closely-woven fabric with a helix of round steel wire to provide reinforcement against collapse and crushing. Most types can be supplied in any length up to 60 feet.

Whatever the service, Goodyear Hand-built Hose is first choice for tough, long-lasting, low-cost operation.



Goodyear Water Suction and Discharge Hose is manufactured in three types—with smooth-bore and fully embedded reinforcement for heavy duty service, especially when the water is corrosive, with rough bore for general service, and with semi-embedded wire for heavy duty applications.

GOODYEAR

Industrial Rubber Products

TRANSMISSION & CONVEYOR BELTING · V-BELTS · HOSE · FENDERS

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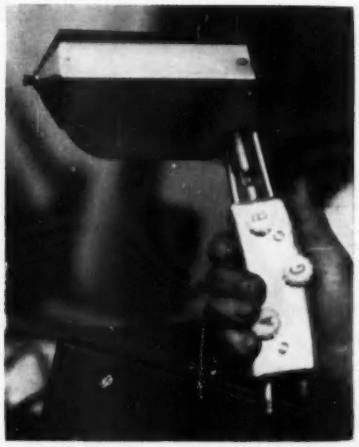
New Materials, Processes, and Equipment

NEW TYPE OF HOT-BLAST WELDING TORCH

Producing a quiet, small-diameter, highly concentrated flame with a temperature in excess of 2000°C, a new type of hot-blast welding torch announced by the BBS Development & Manufacturing Co., of Bristol, not only has the advantage of low initial cost but also of low operational costs, i.e., about one-third that of oxy-acetylene welding and about one-half that of oxy-coalgas welding. Furthermore, it operates from town-gas mains at normal pressure, with air at 0·5 psi, total gas consumption being about 14·5 cu ft per hour and air consumption 7·2 cu ft per hour.

Basically, the unit is a preheated gas-air torch, in which the hot-blast flame is fed with preheated primary air and preheated coalgas (a model operating on bottled butane gas is also available), part of the gas being burnt separately in a preheat unit integral with the body of the torch and so heating the rest of the gas and the primary air to a red heat before they reach the mixing point, at which, as in the conventional torch, the central air jet is surrounded by gas, after which the joint stream flows through a short (red-hot) venturi tube on which the flame is based. The flow is streamlined, so that mixing is by diffusion, which is only partly completed in the venturi, through which the gases pass in less than 1 millisecond.

The resulting flame—essentially a diffusion flame—has a double structure, consisting of a central, internally-maintained flame of red-hot gas burning in the atmosphere. The internally-maintained flame is self-striking, cannot be blown out, and will continue to burn if the torch is played into an inert atmosphere, since with the preheat used (750°C), the gas and air must begin to burn as soon as they meet. This flame is complete in a length of 4 to 5 cm. The external flame, which is not self-striking, since it is burning in cold external air, is much longer, especially if excess gas is used to give a reducing flame, when it may be as long as 45 cm. The two flames blend into one another a few centimetres in front of the venturi, and this is the point of the greatest heating power. The flame is here about 5 mm in diameter and broadens slightly further out.



The flame is markedly hotter than an ordinary gas-air torch flame, and is suitable for such applications as high-temperature brazing, including copper brazing and brazing of thin steel sheets, magnesium and silver soldering, and autogenous welding of brass, aluminium, and aluminium-magnesium alloys. In this connection, the presence of the inert constituent and reducing conditions have facilitated welding and flame-brazing of aluminium alloys which are normally difficult to weld, even with oxy-acetylene.

FLOW-CONTROL VALVES FOR LIQUIDS AND GASES

Intended for use in pipelines to control the flow of liquids or gases, the new range of "Full-Flow" valves introduced by Hydraulics and Pneumatics Ltd., of Wolverhampton, Staffs., is available with diameters ranging from $\frac{3}{32}$ to 4 in. and for pressures between 140 and 5000 psi.

The shut-off unit of the valve is a spherical metal ball, through which a hole is drilled. In the open position, this hole registers with the bore of the pipe, permitting unrestricted flow without turbulence. The ball is mounted in two annular discs, concentric with the pipeline, forming a seal when the valve is closed. Closure of the valve is effected by rotation of the ball via a spindle which passes through a seal above the ball and fits into a cruciform slot. Stops limit rotation of the spindle to an angle of 90 deg. between the fully open and fully closed positions, this 90-deg. movement simplifying remote control by hydraulic, pneumatic, or mechanical means. By resetting the spindle in the cruciform slot, the valve may be adjusted for clockwise or anticlockwise rotation for closure.

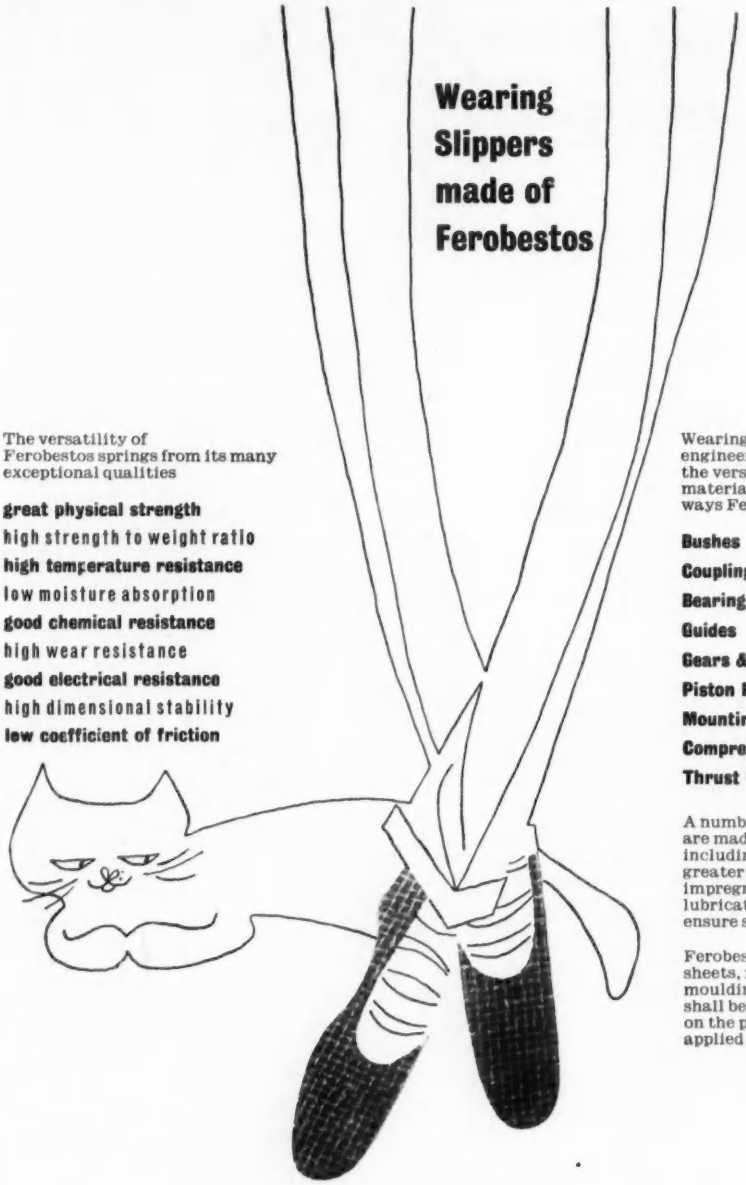
The operational life of the valve is long, and maintenance is extremely simple, as only the seals, which are available in a range of materials to suit varying requirements, are liable to wear, and these can easily be replaced. Furthermore, all moving parts are chromium-plated, to resist corrosion and the consequent possibility of sticking.

MULTI-PURPOSE PINCH VALVES

In the new range of multi-purpose pinch valves produced by W. H. Rowe & Son Ltd., of Southampton, a die-cast construction has been employed for the first time in this type of valve for both the casing and internal components. In addition, specially designed reinforced sleeves are used, all of which are suitable for internal pressures up to 100 psi. These sleeves are available in four grades of natural-rubber or synthetic-rubber materials, i.e., for general-purpose duties, for abrasive materials, for food products (including alcohol and milk), and for petroleum products, tar, and ammoniacal liquors.

The aluminium-alloy die-cast casing is split on its vertical axis for ease of assembly and servicing, and completely encloses the flexible sleeve and operating mechanism. The closing mechanism consists of two die-cast aluminium-alloy anvils, a screwed spindle, and a

Wearing Slippers made of Ferobestos



The versatility of Ferobestos springs from its many exceptional qualities

great physical strength
high strength to weight ratio
high temperature resistance
low moisture absorption
good chemical resistance
high wear resistance
good electrical resistance
high dimensional stability
low coefficient of friction

Wearing slippers is only one of the engineering applications of Ferobestos—the versatile, asbestos-reinforced plastic material. Here are just a few more of the ways Ferobestos can be used:—

Bushes
Coupling Discs
Bearings
Guides
Gears & Rollers
Piston Rings
Mounting Pads
Compressor Blades
Thrust Washers

A number of special grades of Ferobestos are made for particular applications including silicone impregnated for greater heat resistance, and graphite impregnated for more efficient lubrication. Ferobestos gear wheels ensure silence in operation.

Ferobestos can be supplied from stock in sheets, rods, and tubes. Special mouldings can be made to order. We shall be glad to recommend and advise on the possibilities of Ferobestos as applied to any particular industry.

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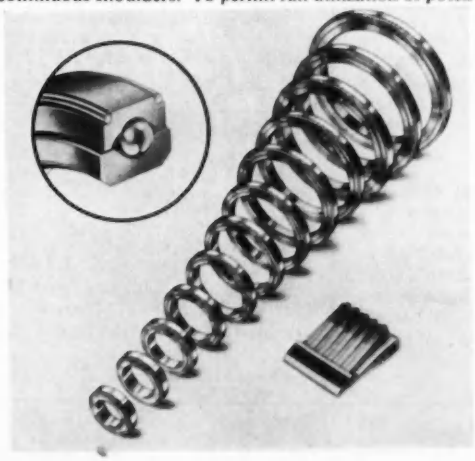
handwheel, which operate to compress the sleeve equally from both sides. The screwed spindle has two right-hand threaded portions, the lower thread being twice the pitch of the upper section. The upper fine-pitch thread engages in a robust nut which is trapped in recesses formed in each half-casing, while the lower coarse thread engages with the rising bridge, which is connected by two rods to the lower anvil. In turning the handwheel clockwise to close the valve, it drops towards the top of the casing by a distance equal to one half of the valve bore, and in doing so provides a ready external indication of the position of the valve. At the same time, the coarse-threaded section of the spindle causes the bridge and lower anvil to rise a similar amount, pinching the sleeve equally about its centre-line. These valves are available in sizes from 1 to 3 in. bore, the 2-in. valve being illustrated.

HIGH-PRECISION BALL BEARINGS

To extend their existing range of high-precision ball bearings, the Split Ballbearing Division of MPB, Inc., of Lebanon, N.H., have introduced two new series of thin-section instrument ball bearings, types TWF and TWA, which are manufactured in twelve sizes with bores ranging from $\frac{1}{8}$ in. to 3 $\frac{1}{16}$ in.

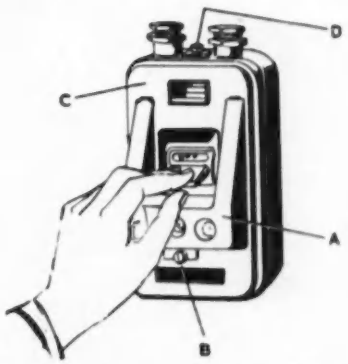
In the type-TWF bearings, integral shields are formed by extending the lands of inner and outer rings to within a few thousandths of an inch of each other. The close-clearance annulus created fills with lubricant and functions as an effective seal without the friction of contact seals. The ball races are of the deep-groove type with continuous shoulders. To permit full utilization of potential thrust capacity of the bearing, no filling slots are employed. Maximum radial and two-directional thrust capacity is ensured by the use of full ball complements, and the closely spaced balls make the bearing ideal for applications where high static capacity is required, or where oscillating movement is present.



The contruction of type-TWA bearings is similar to that of type TWF, but alternate balls are undersized, acting as separators for the load-carrying balls and reducing torque in the bearing.

CIRCUIT-BREAKER WITH DUAL SAFETY FEATURE

Incorporating solid-silver contacts and with all electrical components mounted on a porcelain base housed in a robust metal case as a protection against accidental damage, the new " Sicura Ticino " circuit-breakers introduced by Bassani S.p.A., of Milan, include a novel dual safety feature which not only facilitates servicing and inspection, including changing of fuses, but also ensures that current is cut off before such operations can be carried out.



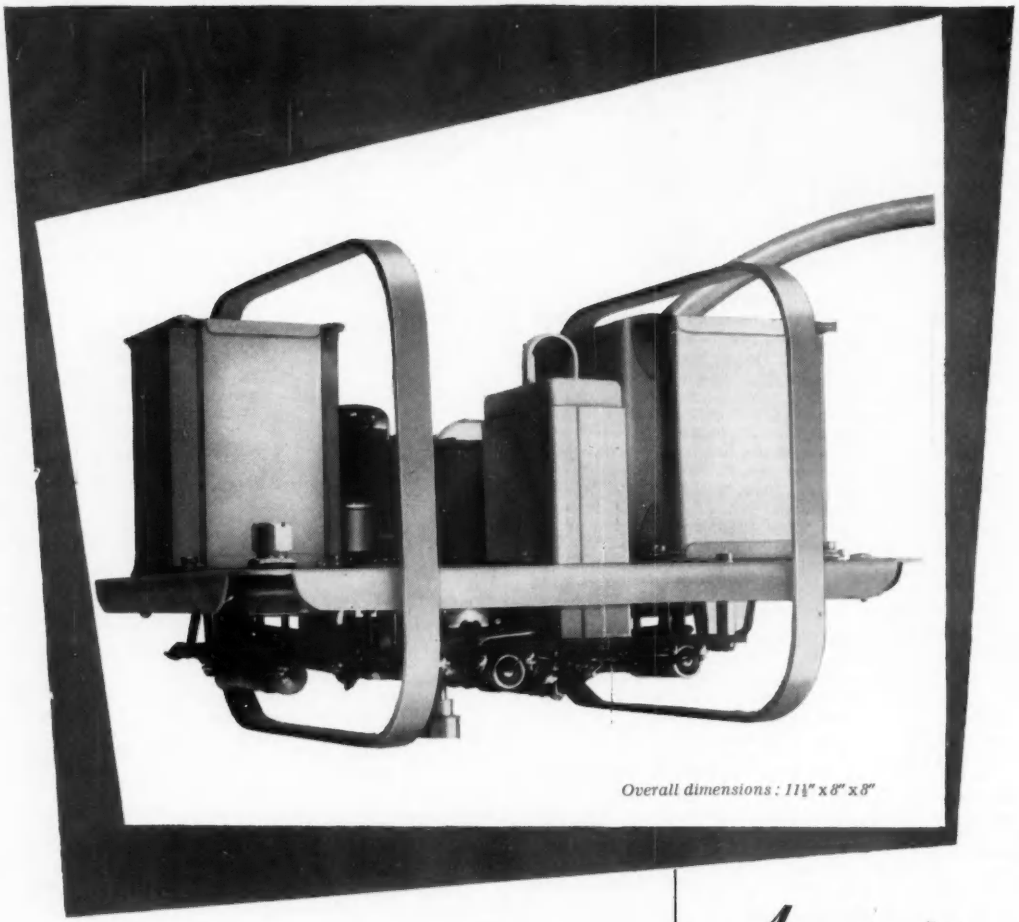
When the lever is depressed to the " OFF " position, as shown in the illustration, the safety-cover *A* can be raised after releasing screw *B*, exposing the fuses for easy and rapid replacement. Similarly, the second safety-cover *C* can be dropped by releasing screw *D*, exposing all components of the circuit-breaker for easy servicing and inspection, without, however, any danger from shock, as all live connections are further protected by an insulating shield.

PNEUMATIC SIZE-CONTROL EQUIPMENT

Stated to provide a completely flexible control for grinding, fine turning, and other manufacturing processes where accurate finishing sizes are required, a new pneumatic size control, designated Model 88, has been developed by Teddington Industrial Equipment Ltd., of Sunbury-on-Thames.

The complete equipment comprises two units, i.e., a gauging head which is fixed to the machine, and a separate control unit, which receives pneumatic signals from the gauging head. The control unit houses all the pneumatic and electrical components for the measurement and control of size. The signal from the gauging head operates pneumatic/electric relays of a new design, and these, in turn, operate electric relays, each of which has a pair of change-over contacts, wired to the machine controls to provide the required control action. Either two or four output relays are provided ; each of these is adjustable and can be set to operate at any point in the range of the instrument. Thus, for example, on a grinding machine, the work cycle could commence with a coarse feed, changing to a slower feed at a predetermined point, with a wheel-dressing operation initiated, where required, and a final spark-out to size. The final relay could be set at the

Synchronising AUTOMATICALLY



Overall dimensions : 11½" x 8" x 8"

The new Austinlite Synchronising Unit cuts out the need for complex and time-taking precautions when switching an A.C. generator into an already running A.C. system. The Unit detects voltages, phases and frequencies and when these are all in step with the system the generator is paralleled and can be safely switched in. More than this, with auxiliary apparatus additional generators can be automatically started up, synchronised, and connected with the system—and later disconnected—as the power demand fluctuates. The Austinlite Synchroniser can again be combined with other apparatus to form a load sharing device between two paralleled generators.
Simple in design, the Austinlite Synchroniser is self-contained, built on a small chassis suitable for back-of-panel mounting. Installation is an easy matter; little or no maintenance is required. It can, if required, be used as a conversion unit with existing generating plant.
Let us give you a more detailed description of this unit.

Austinlite

ELECTRICAL EQUIPMENT

Tailor made by

STONE-CHANCE LTD.

(makers of Sumo Pumps and Stone-Chance Lighthouses), CRAWLEY, SUSSEX.

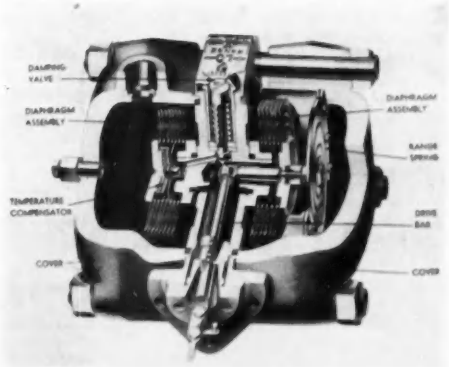
lower tolerance limit to prevent the production of out-of-tolerance parts. Three light signals (red, amber, and green) are provided which operate in sequence with the relays.

The equipment has an adjustable amplification, and may be used for any full-scale range from 0·001 to 0·004 in. For special applications, lower amplifications can be provided. The pneumatic/electric relays are stated to be so sensitive that, when used with the highest amplification (5000), they will operate on a size change of less than 0·000005 in.

Three types of standard gauge heads are provided, each of which is adjustable over a wide range of sizes. For external grinding between centres, an adjustable external caliper gauge is mounted on the wheel shield. In the case of through-feed centreless grinding, a "post-process" gauge is used, the head of which is mounted in such a way that it can check the workpiece as it leaves the work-rest. Where the parts leave the machine in a continuous stream, an adjustable-trend gauging head is used, which is available in two sizes, one covering ½ to 1½ in. o.d., the other from 1½ to 3 in. o.d. When the parts leave the machine at intervals, or where the surfaces of the work are interrupted by flats or undercuts, timed gauging is used. This ensures that control signals are fed to the machine when a workpiece or a full-diameter section of the work is in the gauging position. The timed-gauging head is a caliper unit, adjustable from ½ to 3 in. and fitted with a lever-operated microswitch which provides the timing impulse. As an alternative arrangement, a separate air jet can be mounted on the caliper, giving a pressure impulse to the control unit when a part is in the gauging position. In addition, special-purpose gauging heads for in-feed centreless grinding and internal grinding machines can be provided.

MERCURYLESS DIAPHRAGM METER

A new mercuryless diaphragm meter, for accurate measurement of a range of differential pressures from 20 to 200 in. of water at static pressures up to 2000 psi, has been introduced by Foxboro-Yoxall Ltd., of Redhill, Surrey.



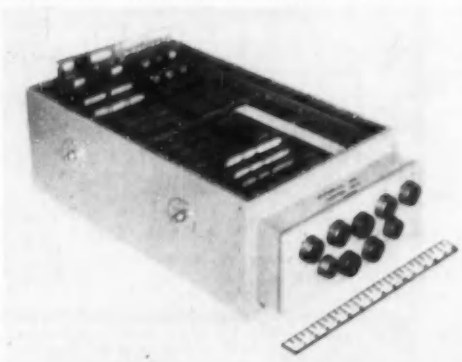
This new instrument, designated Type 37, has a number of special features, including a frictionless flexure using a pivoted drive unit of exceptional sensitivity, positive protection against over-range with no zero shift, a simple method of range change, built-in temperature compensation for all differential ranges, and full-range damping which is adjustable under pressure.

An entirely new and flexible diaphragm assembly is used for the measurement of differential pressure. Preformed discs are welded by a special process and shaped to nest into the adjacent disc, and each is welded to a spacing ring. Excess pressure in either chamber will compress the diaphragm assembly until each pair of discs is nested and the spacing rings have contacted to form a metal-to-metal stop. This assembly is stated to have greater flexibility and higher sentitivity per unit length with less spring rate, than any spun or hydraulically formed bellows for equivalent service.

The drive unit is constructed of solid rods, joined by a metal flexure, and forms a direct connection between the diaphragm assembly and the pen lever. The fulcrum is formed of two similar flexures, and the seal is a flexible bellows capable of withstanding pressures 50% above the meter rating. This drive transmits the smallest measurement changes to the pen with extreme accuracy.

TRANSISTORIZED AIRBORNE COMPUTER

Stated to be the first all-transistor airborne computer in the world and to operate ten times faster than any commercially available airborne computer, the Philco "Transac" C-100 series computer announced by the Philco Corporation, of Philadelphia, Penn., is designed to handle all computational requirements necessary for the control of a jet aircraft from take-off to landing. Furthermore, the use of transistors has reduced the size of the computer to less than 3 cu ft, its weight to about 150 lb, and its consumption to only 60 W d.c.

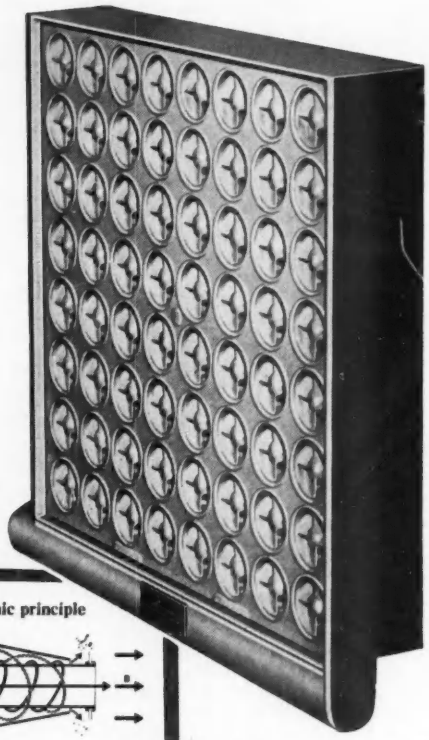


A typical C-100 series computer contains about 3500 transistors, 2300 resistors, 280 capacitors, and 20 core memory planes. Acceptance, processing, and delivery of data are effected in accordance with a stored digital programme, the drum storage being capable of retaining from 1500 to 5000 instructions or numbers.

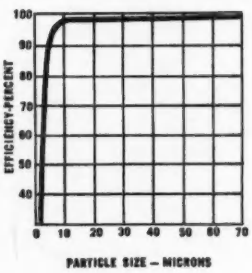
Among other control applications of this computer are auto-pilot, air data (speed and altitude), cruise control (proper altitude for high fuel efficiency), automatic navigation, and engine performance. In addition, it constantly analyses its own operations and, in the case of a military jet aircraft, can also compute weapon delivery and interception. It should, however, be appreciated that, apart from aircraft control, the computer, which will operate under adverse temperature conditions and can withstand severe shocks and vibration, can also be used for other mobile or industrial control applications.

Engine air filtration without maintenance

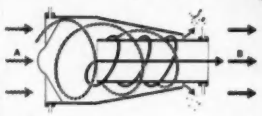
Reciprocating engines and air compressors attain their higher efficiencies through the use of smaller working clearances and relatively high speeds of revolution. Clean air, essential to such high performance machines, is reliably obtained at low cost through Rotonamic filtration.



Graph of Rotonamic efficiency percentage plotted against dust particle size.



The Rotonamic principle



Air entering a Rotonamic panel at A is centrifuged at speed by the helical vanes. 10% of the air conveys dust to the bleed-off tube at the base of the panel. The remaining 90%, cleaned and filtered, reverses direction, enters the tube and exits at Point B.

The illustration shows a Rotonamic panel comprising multiple static vanes which impart a whirling motion to the air entering the panel. The dust is centrifuged from the air and is bled off to atmosphere or dust bin.

Rotonamic air filters are self-cleaning and have no working parts to wear. These filters are extremely efficient and easy to maintain. Please write for leaflet FRC9.

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for high efficiency at low cost . . . interpose an

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NEWS OF THE MONTH

PERSONAL

Mr. Leonard Baker, M.I.Mech.E., A.M.I.P.E., has been appointed deputy managing director of Coventry Gauge & Tool Co. Ltd.

Wickman Limited announce that **Mr. J. Hodkinson** has been appointed a director of the company with overall responsibility for its machine tool interests. He will retain his present appointment as managing director of Machine Tools (India) Private Ltd., a company associated with Wickman Limited.

Mr. H. E. Cooper, B.Sc. (Hons.), has been appointed managing director of G. A. Harvey & Co. (London) Ltd. **Mr. P. T. Bliss,** sales director, will retire on December 31; he will be succeeded by **Mr. I. A. Marriott.**

British Physical Laboratories announce the appointment of **Mr. D. J. Davis** as their sales manager in succession to **Mr. D. G. Ashton Davies,** who is taking up an appointment with E.M.I. Electronics Ltd.

Mr. J. F. Morton, formerly works manager, has been appointed to the board of Herbert Hunt & Sons Limited as works director. **Mr. R. H. Carter** has been appointed sales manager.

Sigmund Pumps Limited announce that **Mr. H. P. Lord, A.F.C., B.Sc.,** the present general sales manager, has been appointed to the board of the company.

Keelavite Hydraulics Limited announce that **Mr. N. B. Brooks, M.C.,** has recently joined their board of directors.

Mr. Edward Tauchert, M.I.Mech.E., F.B.H.I., formerly works director, has been appointed managing director of Venner Limited.

Babcock & Wilcox Limited announce the appointment of **Mr. J. H. Prole** as assistant manager of the company's Mechanical Handling Division.

Mr. I. F. Fisher, M.B.E., has been appointed general works manager of British Timken Limited, in which position he will be responsible for the management of their factories at Duston and Daventry. He was formerly works manager at Duston, where he will be succeeded by **Mr. S. H. Jakeman.**

Viscount Falmouth has been re-elected president of The British Internal Combustion Engine Research Association. **Sir Harold Roxbee Cox, Mr. H. N. Pemberton, Professor O. A. Saunders,** and **Brigadier S. A. Stewart** have been re-elected vice-presidents. **Rear-Admiral W. F. B. Lane** has also been elected vice-president. **Mr. G. B. R. Feilden** and **Mr. V. H. Hopkins** have been elected to the Council in succession to **Mr. G. W. Bone** and **Mr. A. C. Yeates,** who retired by rotation. **Mr. B. D. Giordan** will be chairman, and **Mr. Hopkins** vice-chairman, of the Council.

James Hodgkinson (Salford) Limited, who recently acquired Bennis Combustion Limited and J. & J. Neil (Temple) Limited, announce that **Mr. R. Yeoman** has been appointed general manager for the foundries of the group.

MR. HOWARD CLAYTON-WRIGHT

It is with deep regret that we announce the death, following a short illness, of Mr. Howard Clayton-Wright, on September 26, at the age of 71. Mr. Clayton-Wright was chairman of Howard Clayton-Wright Ltd., of Wellesbourne, Warwickshire.

BUSINESS NOTES

Blaw Knox Limited, of London, announce the formation of a new affiliated company, the **Blaw Knox Chemical Engineering Company, Limited,** with registered offices at 90/94 Brompton Road, London, S.W.3. Owned jointly by Blaw Knox Limited and their Associates, the Blaw-Knox Company of Pittsburgh, Pa., the new company will design, engineer, and erect process plants, as well as process equipment, for the chemical and petroleum industries and will serve and develop the British and overseas markets.

It is announced by **Keelavite Rotary Pumps and Motors Ltd.** that the name of the company is now **Keelavite Hydraulics Ltd.** The address and telephone number of the company remain unchanged.

Booker Brothers, McConnell & Co., Ltd. announce that **Bookers Engineering Holdings Ltd.** (a member of the Booker Group of companies) has purchased 90% of the issued share capital of **Sigmund Pumps Ltd.** Mr. Miroslav Sigmund, the managing director of Sigmund Pumps Ltd., retains a 10% interest in the company and remains managing director.

It is reported by **Wickman Limited** that they have acquired a majority holding in **Brasmac Industria e Comercio S/A,** of São Paulo, Brazil, with a view to furthering the Wickman Group's exports to, and expanding their tungsten carbide interests in, this industrial market.

Fredk. A. Power & Sons (Box Strappings) Ltd., of Landor Street, Birmingham 8, will in future be known as **Power Strappings Systems Ltd.** Policy and management remain entirely unchanged.

As their diesel engines are complementary and jointly represent a power range of 20 hp and above, **The English Electric Company Limited** and **W. H. Dorman Limited,** of Stafford, have entered into an agreement whereby each company will promote the sale of the other's products.

Alfred Herbert Ltd., of Coventry, have been appointed sole selling agents in the U. K. and Eire for the planing machines and equipment manufactured by **Planers (Huddersfield) Ltd.**

A new manufacturing agreement is announced between **Armstrong Siddeley Motors Ltd.,** of Coventry, and **Clark Bros. Co.,** division of **Dresser A.G.,** a leading American manufacturer of gas turbines and heavy compressors. The terms of the agreement provide for licensed manufacture in the U.K. of gas turbines designed and made in the U.S.A. by Clark Bros.

Flexibox Limited, of Trafford Park, Manchester, announce that they have appointed **John Turner & Co.,** of 25 Collingwood Street, Newcastle-upon-Tyne, as agents for the North-Eastern area of Great Britain.

An international group has been formed for the manufacture and sale of the Casinghini patent "Tankerheat" cargo-heating system for tankers, the members being **E. Green & Son Ltd.,** of Wakefield, **F. Casinghini Economizzatori Green,** of Milan, **S.A. L'Economiseur Green,** of Paris, and **Green Fuel Economiser Co. Inc., of Beacon, N.Y.** The Green companies in Britain, France, and the U.S.A. will manufacture in their respective countries standard "Tankerheat" elements similar to those designed and manufactured by the Italian company, and technical and commercial liaison has been established between the members of this group and their associated companies.

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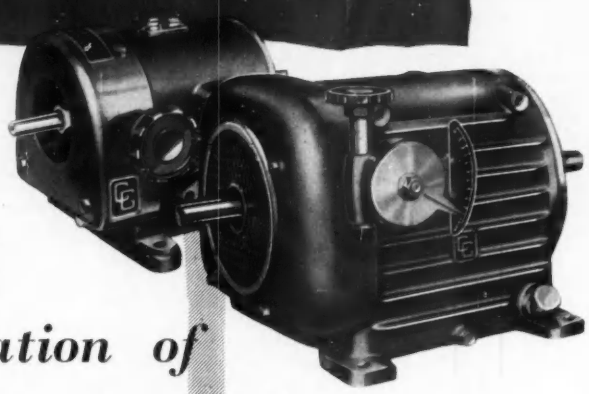

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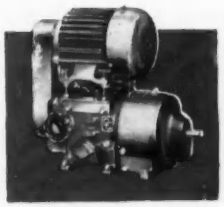

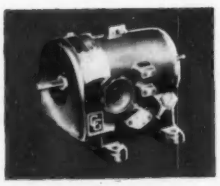

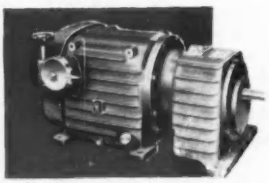

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CONTRACTS

The Incandescent Heat Co. Ltd., at Smethwick, has recently been awarded a contract worth more than £500,000 for a large coil-annealing installation at the new steelworks of the Sociedad Mixta Siderurgia Argentina (SOMISA). The order, obtained against strong continental competition, is for 25 single-stack coil-annealing furnaces with 72 bases, 32 forced-cooling hoods, and 3 exothermic gas atmosphere plants, each rated at 10,000 cfh. The furnaces are built to the design of the Lee Wilson Engineering Co. Inc., of Cleveland, U.S.A., for whom Incandescent are manufacturing licensees. The plant will handle coils up to 60 in. in diameter in stacks up to 168 in. in height, and will anneal annually 300,000 tons of cold-reduced sheet and tinplate.

The Independent Television Authority has placed a substantial contract with E.M.I. Electronics Ltd., for what will be the tallest television aerial mast in the Commonwealth. The 1000-ft mast will be situated at Mendlesham, Suffolk, and will carry ITV's East Anglia programme from the studios of Anglia Television in Norwich. The order includes the supply and erection of the mast, the special directional aerial system, and the feeders from the transmitter. Known as the Mesny Type, the aerial system is of a special E.M.I. design not used before in this country.

British Insulated Callender's Construction Co. Ltd. are acting as sub-contractors for the design, supply, and installation of the aerial supporting mast ; the steelwork will be fabricated by Painters Bros. Ltd., of Hereford.

A contract worth £500,000 for plant for a free-piston gas-turbine power installation has been awarded by Finland to National Free Piston Power Ltd. This will be the first free-piston gas-turbine power installation in Northern Europe. The free-piston gasifiers will be manufactured by National Gas & Oil Engine Co. Ltd., of Ashton-under-Lyne, under licence from Alan Muntz & Co. Ltd., Pescara, and SEP, while the gas-expansion turbines will be made by the Brush Electrical Engineering Co. Ltd., of Loughborough. The plant, which will form an extension to the existing 6-MW steam station at Riihimaki, will consist of two 6-MW gas-expansion turbo-alternator sets and sixteen GS34 free-piston gasifiers and all the necessary ancillary plant. This new plant will be operated to meet peak loads, as well as doing stand-by duty to the base-load plant to supplement the Finnish hydro-electric grid supplying power to the industrial and rural area around the towns of Riihimaki and Hyvinkaa, about 100 miles north of Helsinki.

INTEGRATED PRODUCTION CONTROL WITH THE HOLLERITH ELECTRONIC COMPUTER

The first attempt in Great Britain to achieve integrated electronic-computer control of production planning processes and plant loading as a means to the more effective deployment of manufacturing resources is now in progress in one of the British Tabulating Machine Company's main Letchworth factories and was recently demonstrated to the Press.

Production control comprises a multiplicity of interrelated functions, involving programme breakdown for translation of a sales programme of end-product requirements into a production plan for manufacture, plant loading to determine the total load per machine group available in each manufacturing period and to allocate time for specific machines and groups for carrying out various operations, progress control for comparing actual and projected performance and adjusting discrepancies, and stock control to ensure availability of material. It will therefore be appreciated that an enormous number of calculations is needed to satisfy such requirements, and it is here that the Hollerith HEC general-purpose electronic computer plays an invaluable part in solving the problems of production management.

Although actual operation of the Hollerith computer installation is as yet measurable only in weeks and, in any case, extends only to part of the British Tabulating Machine Company's production in Letchworth, the positive results so far achieved point unmistakably to ultimate benefits, which may be summarized as follows :

(1) The ability to give more rapid effect to varying sales demands and a consequently enhanced service to customers.
(2) A much more rapid production programme change-over than has hitherto been achieved.
(3) A reduction in production time (within cycle time) to a realistic minimum.
(4) The production of more accurate and more timely management information, including some significant data and a number of illuminating comparisons not previously available. One effect of this has been a review of the volume and deployment of sub-contracting commitments.

NEW FACTORY FOR SANDVIK SWEDISH STEELS LIMITED

The new £250,000 Dandvik Swedish Steels Limited factory at Halesowen Birmingham, recently opened officially by the Swedish ambassador to Great Britain, is attractively planned with an eye to future expansion. Constructed on a site of approximately 2½ acres, the premises are divided into three main groups, i.e., administration, production, and storage, each with its own ancillary services and spaces.

The office block, with a total area of 18,200 sq ft and permitting a subsequent extension of 4000 sq ft, comprises office space and stores, a kitchen and dining-room, a caretaker's room and guest-room, a boiler-house and fuel store, and toilets and miscellaneous services. The works section, with a total area of 27,000 sq ft and permitting an extension of 20,000 sq ft, consists of a garage, a warehouse, a workshop, and toilets, etc. The warehouse and factory have a level floor area, flexible enough to be divided into heavy storage and light storage and production. The large area for heavy storage is served throughout by an overhead crane, the remainder of the area being served by fork-lift trucks. A special point is the provision of adequate heating and insulation so combined as to ensure that no condensation occurs throughout the year, thereby eliminating the possibility of damage being suffered by products.

INCORPORATED PLANT ENGINEERS

The transfer of the headquarters of the Institution of Incorporated Plant Engineers from the Midlands to their new address at 2 Grosvenor Gardens, London, S.W.1, marks an important stage in its progress, and it is interesting to recall that, whereas membership at the end of 1946 was only 120, it is now nearly 4000, of whom more than 500 are overseas, spread through mos countries int the world.

Education and training have been a main concern of the Institution from its inception, and the Education Committee (in February 1947) was one of the first to be appointed by the Council. This committee took a major part in the establishment of the City and Guilds of London Institute's Certificate in Plant Engineering (Course 187). Its other main activity has been the organization of the remarkably successful refresher courses for senior works and plant engineers, held each winter at university level in various industrial centres.

The City and Guilds Course in Plant Engineering offers a syllabus with a less academic and more practical content than H.N.C. and, it is believed, is a suitable alternative for some young men with O.N.C. The course is based on the view that a plant engineer does not practise solely one of the three traditional branches of engineering, but needs as a foundation a broad general knowledge of all these and also of other subjects.

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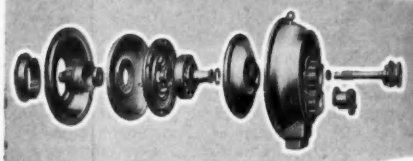

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NEW TECHNICAL BOOKS

Gas Turbines for Aircraft. By Arthur W. Judge. 446 pp., 220 illustrations. Publishers : Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price : 60/–.

Written with this well-known author's usual conciseness and clarity, combined with a judicious use of numerous diagrams and photographs, this interesting and authoritative volume bridges the gap between the normal descriptive and elementary type of textbook and the more academic kind by considering briefly the history and development of the light gas turbine and then the results of theoretical and experimental investigations, followed by accounts of typical gas turbines and their component systems, e.g., the fuel, combustion, lubrication, starting, and control systems. In addition, the associated subjects of engine failure, maintenance, exhaust silencing, thrust reversal, high-temperature materials, and special types of gas turbines, including those for helicopters, have been considered. A section devoted to the elementary thermodynamics of the gas turbine has been included for the benefit of students and others who may be interested.

It is realized, however, that with the considerable amount of technical information now available it is not possible to give more than a brief account of any particular branch of the subject in a volume of this kind. Nevertheless, wherever considered necessary, the reader is referred for fuller particulars to the original sources of information, a list of nearly 150 such references being included.

Automatic Measurement of Quality in Process Plants. 326 pp., 124 illustrations. Publishers : Butterworths Scientific Publications, 4 & 5 Bell Yard, London, W.C.2. Price : 50/– (postage 1/6).

Representing the proceedings of a Conference held at Swansea between September 23 and 26, 1957, by The Society of Instrument Technology, these edited papers provide a valuable and objective survey of the various techniques available for quality control in process plants. In this connection, one of the most striking industrial developments in recent years has been the progress made in the scientific processing of raw materials such as oil, cellulose, metalliferous ores, natural fats, rubber, leather, and food. With the rapid increase in the scale of these industries, the continuous process has provided the economic solution, bringing with it the increasing need for automatic control, with all the advantages it has to offer in speed, accuracy, quality of product, and saving in man-power.

The papers, 25 in all, have been divided into six distinct sections, i.e., (1) The Adaptation of Laboratory Techniques to Plant Measurement (4 papers), (2) Some Techniques for Gas Stream Analysis (6 papers), (3) Liquid Stream Analysis (2 papers), (4) Spectrometric Methods (4 papers), (5) Some New Techniques for Fluid Stream Analysis (4 papers), and (6) Measurement of Some Physical Properties (5 papers).

Aircraft and Missile Propulsion (Vol. I : *Thermodynamics of Fluid Flow and Application to Propulsion Engines*). By M. J. Zucrow. 552 pp., 199 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price : 92/–.

This interesting and authoritative book is the first of a three-volume series which discusses the principles of the technology pertinent to turbo-prop, turbo-jet, ram-jet, liquid-propellant rocket, and solid-propellant rocket engines. As such, it provides students and practising engineers with an understanding of the functioning and operating characteristics of these engines for the propulsion of winged aircraft and missiles, guided and unguided, at high speeds.

The present volume is concerned with the thermodynamics of fluid flow and its applications to propulsion engines. To ensure full understanding, Professor Zucrow has made special efforts to present the subject matter clearly. To this end, all derivations are explained in detail, copious references are provided at the end of each chapter, and an unusually large number of illustrative problems is worked out completely. In addition, numerous exercise problems, together with their answers, are included.

Principles and Applications of Random-Noise Theory. By Julius S. Bendat. 446 pp., 106 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price : 88/–.

Especially intended for students, research scientists, and practising engineers, this well-written book is a systematic development of fundamental topics, explaining the basic idea of random-noise analysis and optimum filtering techniques in easily understandable terms. Methods are given of formulating certain difficult noise problems, of deriving their solutions, and of obtaining proper physical designs and interpretations, while the basic fundamentals are blended with material on probability and statistics, so as to illustrate the importance of applying these factors conjunctively in the analysis of random noise.

The presentation includes discussions on probability theory, random-noise analysis, random processes, engineering systems, correlation functions, power-spectral density functions, and optimum filters. A great deal of the material relative to power spectra, optimum prediction and filter theory, analogue computer techniques, detailed statistical-error analysis for correlation measurements, advanced optimum time-variable designs, and the zero-crossing problem appears for the first time in book form. The book also contains a full treatment of Rice's presentation of random noise and its application to various problems.

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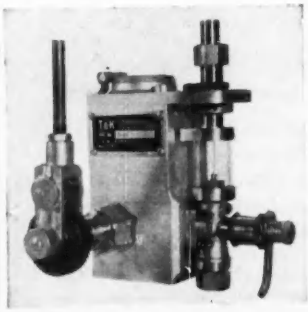

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2. Hydraulic Cylinders and Control Valves. A range of hydraulic cylinders and control valves is fully described in an illustrated 16-page brochure, and includes standard cylinders, foot-mounted cylinders, base-mounted cylinders, flange-mounted cylinders, trunnion-mounted cylinders, and special cylinders, hand-operated, solenoid-operated, speed-regulating, and non-return valves, and power-pack assemblies. The cylinders are designed for working pressures up to 1 tsi and are made from bright-drawn steel tube honed internally to a very fine finish and fitted with steel end-caps. Adjustable hydraulic cushioning can be fitted into one or both ends of the stroke.

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3. Transformation Characteristics of Direct-Hardening Nickel-Alloy Steels. A new edition of their atlas of isothermal-transformation diagrams of nickels has been published by a leading British manufacturer. In addition to isothermal diagrams and end-quench hardenability data, this excellently produced 92-page publication incorporates supplementary information in the form of continuous-cooling transformation diagrams, covering the range of cooling rates involved in the oil-quenching of bars of 1 to 6 in. in diameter, and helping to resolve the difficulties of practical application arising from isothermal data alone.

4. Industrial Electric Surface Heaters. Full descriptions are given in a well-produced and illustrated 44-page catalogue of a comprehensive range of electric surface heaters, basically similar in many ways to electric blankets. This method of heating, which was pioneered by the manufacturers, is widely applied in many industries, including the chemical and pharmaceutical industries, paint works, general engineering, and atomic power plants.

These heaters are available in a wide range of types, sizes, and materials, suitable for use in an extremely large variety of applications, including mixing vessels, heaters, valves, pumps, and instruments. In addition, a range of flexible electric heating tapes is described, specially intended for such applications as fuel-oil lines, and pipes carrying chemicals, bitumen, and food products.

5. Universal Clarifier for Coolants. A new universal clarifier described in an 8-page illustrated booklet is designed to remove automatically from coolants all types of swarf and grinding-wheel abrasive produced during grinding and similar operations. The clarifier is completely automatic in operation, all that is required being occasional emptying of the sludge-box.

The unit is so designed that contaminated coolant flows into a trough of special filtering material carried on an endless wire-mesh conveyor, which automatically draws along fresh filtering medium. Though this medium retains all dust and swarf on its surface, it is still sufficiently porous to permit free and uninterrupted flow of filtered coolant into the sump of the clarifier, whence it is returned by a pump to the grinding head. When the filter becomes saturated with contaminants, a micro-switch automatically causes a motor to move the conveyor forward, causing a clean filtering trough to be formed almost immediately and automatically depositing the loaded filtering medium into the sludge-box.

6. Gas Circulators for Radioactive Circuits. Details are given in an illustrated 4-page brochure of a gas circulator for radioactive circuits, the main feature of which is the integral arrangement of the induction-motor squirrel-cage and the centrifugal impeller on a single robust shaft mounted in self-acting gas bearings. This rotating assembly is housed inside a cylindrical, welded mild-steel casing, hermetically sealed by welding the end-cover when making the final closure. The circulator has numerous applications in circuits for which hermetic sealing and long maintenance-free life are specified at operating pressures up to 350 psi and temperatures up to 350°C.

7. High-Grade Tool Steels for Cold Work. Issued by a British firm of specialists in the manufacture of tool steels, a 36-page booklet gives details of a wide range of tool steels for cold work, including drawn and ground tool steels. These steels are supplied in the annealed condition, ready for machining, and are available in a variety of forms, including black bars in round, square, or rectangular sections ; sawn blanks and forgings ; centreless ground bars ; and cold-drawn wire.

8. Metal-Forming Machines. A 12-page booklet, published by one of the oldest manufacturers in England of hydraulic equipment, illustrates and describes actual installations of their metal-forming machines for every application in the working and forming of steel plate. The range of equipment covered includes horizontal bending presses, bending and straightening machines, flanging and forming presses, dishing and flanging presses, general-purpose presses, heavy-duty hydraulic press brakes, plate-curving presses, and complete-circle plate-bending rolls.

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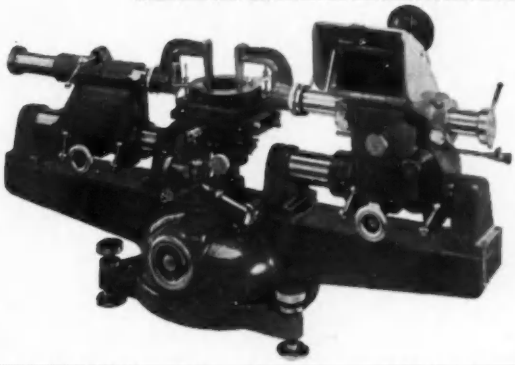

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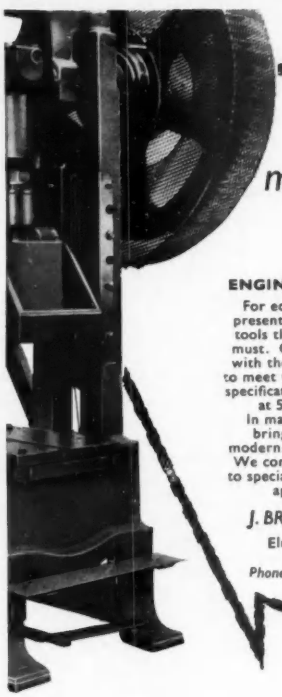

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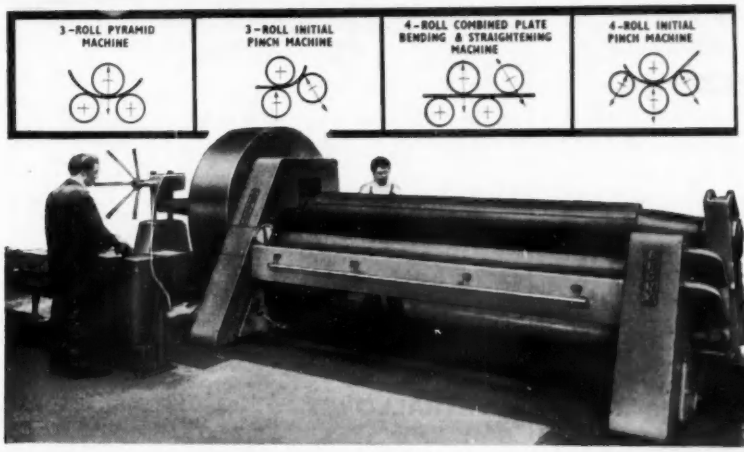
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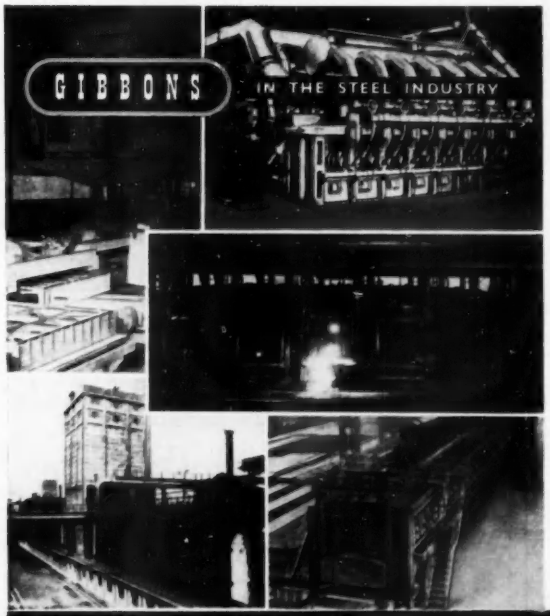

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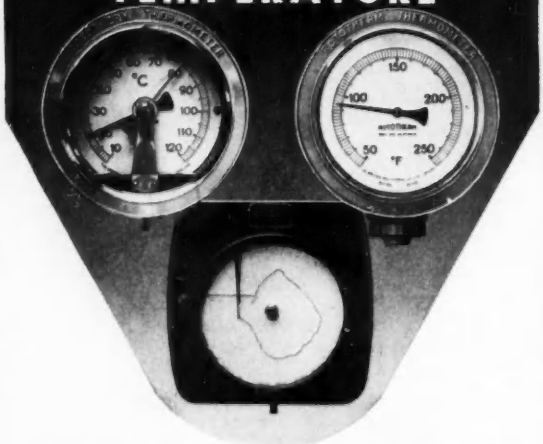

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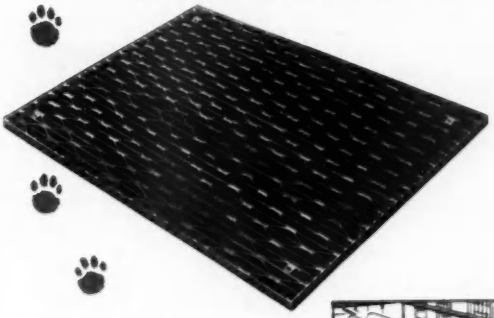

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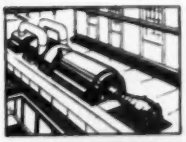

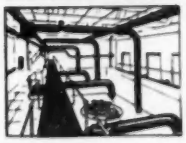

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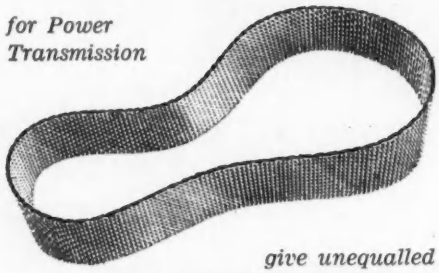

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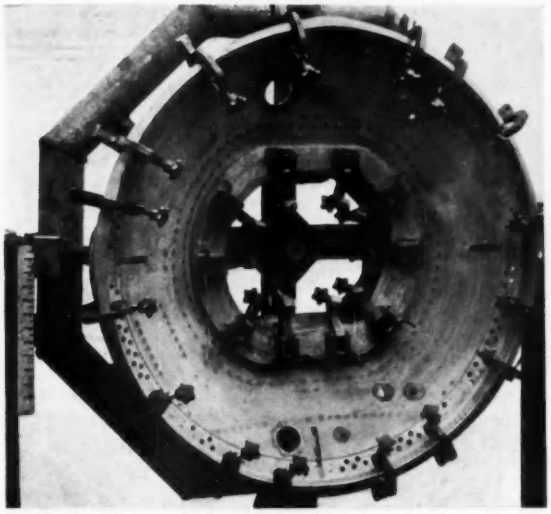

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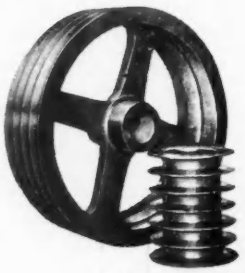

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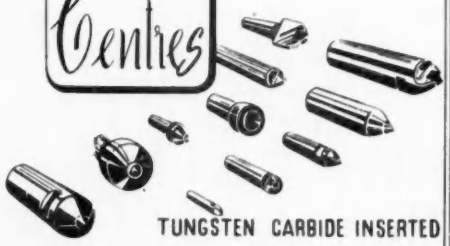

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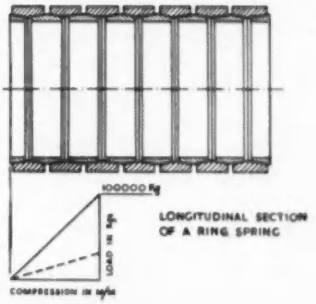

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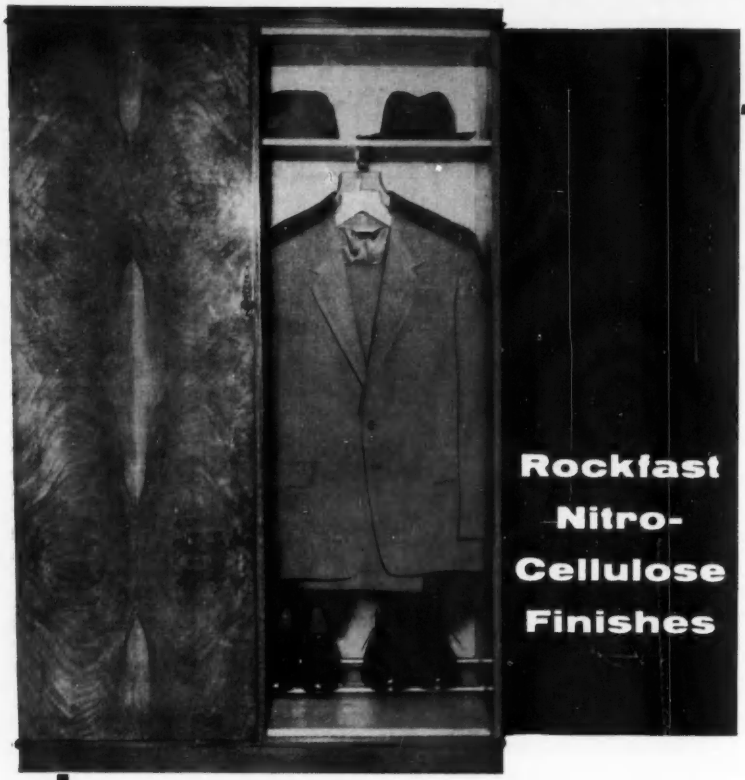

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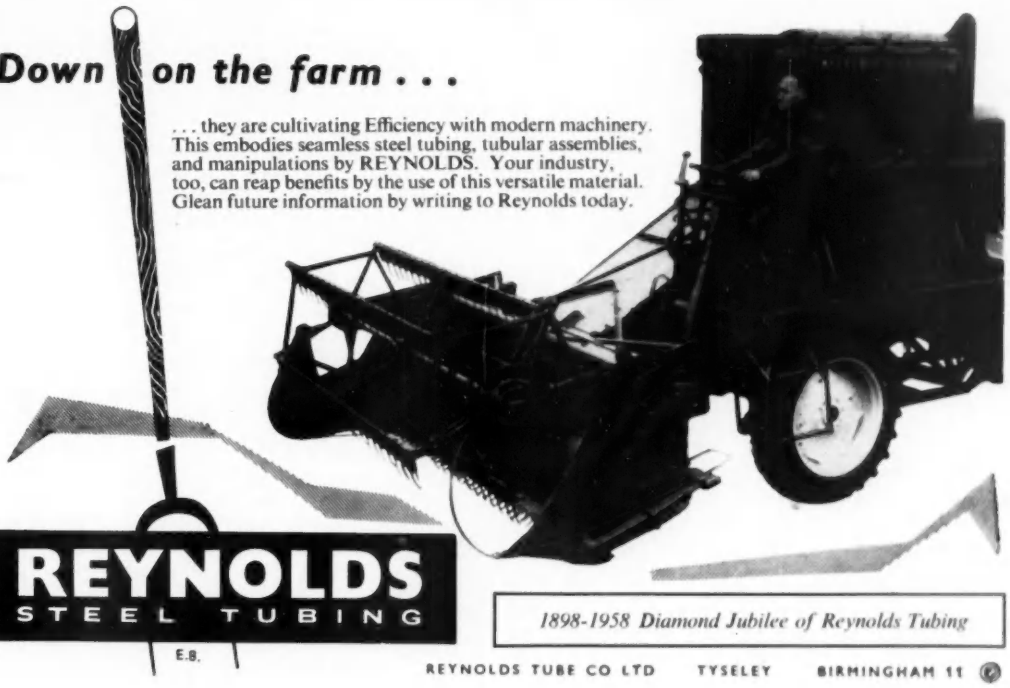

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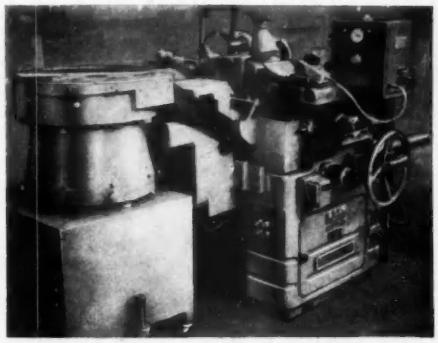
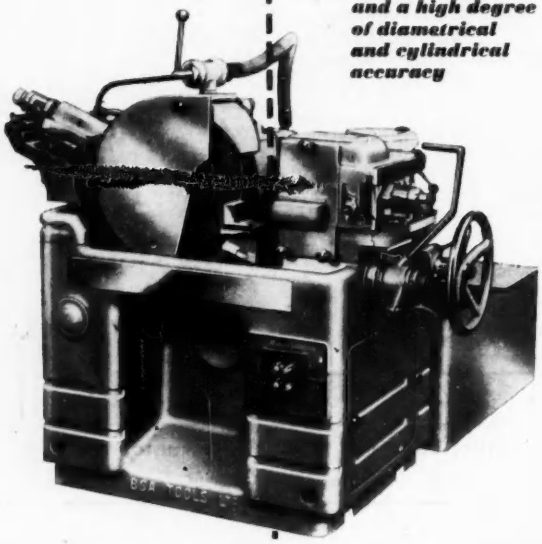


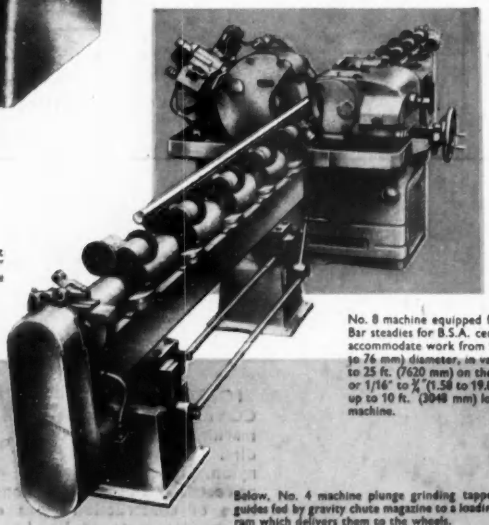
No. 4 machine equipped for automatic sizing-control and automatic infeed. Vibratory type hopper. Special bolts 7/16" × 2 7/16" (11 mm × 73 mm) long are ground to a tolerance of 0.0005" (0.012 mm). Production: 700 bolts per hour. Sizing-control incorporates automatic grinding wheel head feed-compensation.



No. 4 MACHINE

Work diameter *	1/16" to 3" (1.58 to 76 mm)
Grinding wheel Speed:	1270 rpm.
Control wheel Speeds	4
Width of wheels	4" (101 mm) or 5" (127 mm)
Main motor:	10 h.p.

*(With special equipment work down to 0.010" (0.254 mm) dia. can be accommodated).

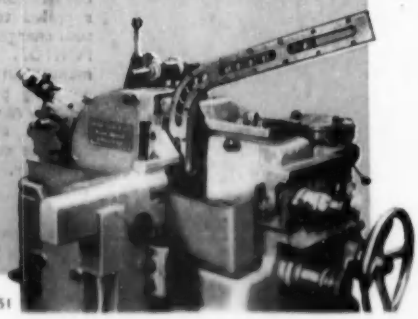


No. 8 machine equipped for bar grinding. Bar steadies for B.S.A. centreless grinders accommodate work from 1/16" to 3" (1.58 to 76 mm) diameter, in various lengths up to 25 ft. (7620 mm) on the No. 8 machine, or 1/16" to ¾" (1.58 to 19.05 mm) diameter up to 10 ft. (3048 mm) long on the No. 4 machine.

No. 8 MACHINE

Work diameter	⅛" to 6½" (3.17 to 167 mm)
Grinding Wheel Speed	1180 rpm
Control Wheel Speeds:	12
Width of Wheels:	5" (127 mm) or 8" (203 mm)
Main Motor:	20 or 40 h.p.

Below, No. 4 machine plunge grinding tappet guides fed by gravity chute magazine to a loading ram which delivers them to the wheels.



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